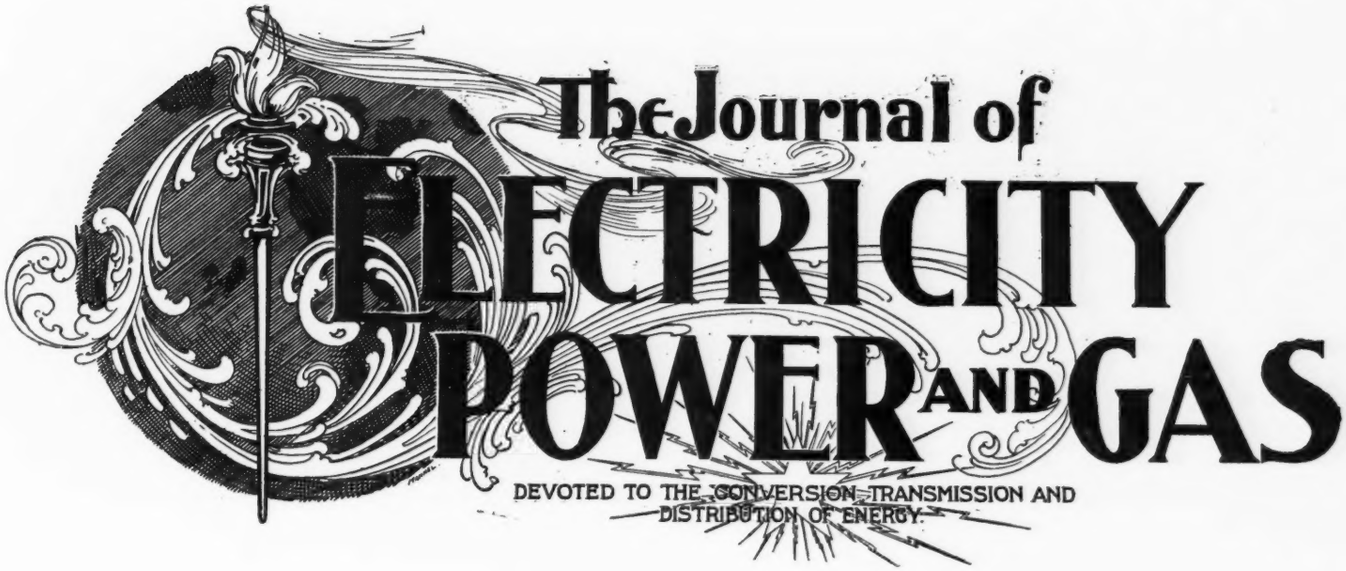

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The Tamalpais Meeting of the Transmission Association.

Proceedings of the Fourth Annual Convention Held at the Tavern of Tamalpais, June 19-20, 1900. A Complete Report of Papers Read and Discussions Thereon.

THE Fourth Annual Convention of the Pacific Coast Electric Transmission Association, held at the Tavern of Tamalpais on Mount Tamalpais, California, on June 19th and 20th, will long be remembered because of the perfectly ideal spot selected as the place of holding the meeting and because of the inestimable value of the papers and discussions that were brought before it. The features pertaining to the social side of the Convention are related on another page and the business transacted by the Convention is given in full in the following stenographic report.

OFFICIAL BADGE.

The convention was called to order on Tuesday, June 19th, at 1:30 p. m., by the President, Pce. A. Poniatowski, who, in dispensing with procedure according to the usual formal order of business, opened with the following remarks:

THE PRESIDENT. Our last meeting was held a year ago. In contradiction with my promise that we would have monthly meetings, we are still on the schedule of yearly meetings. I feel like extending apologies for this, but we are all very busy, and I have been unusually busy this year, having been out of the State most of the time, and I have not been able to do much for the Association—in fact, to do anything at all. I simply hope somebody else will do better. Meetings should be held more frequently; every three months, if not monthly, at a more central point than Mount Tamalpais. Every one of us should try to keep things progressing. I heard in the East a number of people mention the Association and talk about it, and there they consider it to be a very formidable institution. I don't see why it shouldn't become a very formidable institution in a way, and a very useful one. Our transactions will no doubt be of more interest outside the State than amongst ourselves, and it looks very much as if it was, in the way of long-distance transmission, going to keep up its record; in other words, I think the year 1901 will see two or three more long-distance-record lines in California, which this Transmission Association has really the right to be proud of. I say this Association, because people in the East and abroad, reading our transactions, are in some measure giving credit to the Transmission Association for the work accomplished by its individual members.

As a remembrance of my past chairmanship, I now take pleasure in presenting each member of the Association with a little souvenir in the form of a button.

Last year we had thirty-two members. We have seventeen or eighteen applications for membership—mostly associate members. I think this is a good sign of growth and a valuable increase to our sphere of action and influence.

I will now call the meeting to order and open the proceedings with Doctor Perrine's paper.

MR. LEE. Before starting in the reading of this paper I must offer a note of apology. I don't know whether it has ever fallen to the lot of any of you to read another man's paper. There is always a personal equation, I think, in a paper, and it is apt to be a big one in this case. A particular disadvantage is that I only received the paper this morning, and I just had time to glance over it. Possibly I may not, the first time, get the right sense. The title of the paper is "Regulation in Long-Distance Transmissions," by Frederic A. C. Perrine.

Mr. Lee then read the following:

REGULATION IN LONG-DISTANCE TRANSMISSIONS.

BY FREDERIC A. C. PERRINE, D. SC.

WHEN we speak of the regulation in an electric plant of any kind, it is common to refer only to the maintenance of the proper voltage at the lamps or the motors of the customers, but in order that a proper system of distribution in the regulation for the customer be obtained, it is necessary in the design of the plant to consider regulation at many different points and of several different kinds in order that the service offered may be perfectly satisfactory. In the first place, the periodicity of an alternating-current supply must be maintained constant, which means that the water wheels must be adapted with regulators which will produce a constant speed of running, irrespective of changes in the load and changes in the voltage. Passing the water wheels and approaching the generators we find that here the regulation is one of voltage, and that in the generating station the voltage must vary with varying load, even though the customer may require a voltage as constant as the periodicity. The step-up transformers in the generating station are involved as one of the factors which determine the amount of voltage variation which the generator must provide, and passing these transformers we find in the line a disturbing element that must be carefully considered, even though at its end a voltage as nearly constant as may be must be attained. The final adjustment of the voltage to suit the customers needs is provided in the sub-station where the step-down transformers are located.

It is the writer's purpose to call attention to the difficulties of regulation at each one of these points and to point to general solutions in overcoming such difficulties as may be presented without trying to offer the definite solution of any particular case. This discussion, there-

fore, may serve merely to make the ideas already familiar to us all more concrete, and to call attention to a few neglected conditions in obtaining a perfectly satisfactory service.

As has already been said, the regulation of the water wheels must be such as will maintain constant speed, and such constancy is obtained in a different manner with high and low head wheels. With wheels operating under a low head of water, large penstocks in which the water moves at a low velocity are generally available, and, in consequence, regulation of such wheels is always provided by variation of gate opening. This system of regulation, while certainly difficult to accomplish on account of the weight of the moving parts, is ideal in respect to conservation of water, the water allowed to flow being in some respect proportionate to the load. We say "in some respect," on account of the fact that the efficiency of all water wheels falls very materially as the load decreases. This difficulty of efficiency variation produces a difficulty in regulation, for the reason that a certain load change at full load requires a smaller gate variation than the same load change at one-quarter load, and in order to surmount this difficulty a recent Italian designer has attempted to close bucket openings in place of the gate openings in his wheel, thus operating certain buckets always with full volume of water and maintaining full bucket efficiency at all loads. Such wheels have not been built in this country, although a set has been contracted for by the Montmorency Electric Power Company at Quebec, where the wheels under this design are now being installed.

The good regulating points of the low head wheels are sacrificed whenever the velocity of flow or the length of a column in the penstocks is increased, and their regulation is correspondingly improved by shortening the penstocks, even to its entire obliteration, and operating the wheels in the forebay itself.

However obvious this may seem, it is nevertheless the fact that in an eastern plant recently installed and not yet in operation, the engineers have led the water from the forebay through 160 feet of entirely unnecessary penstocks laid level.

Low head wheels are of far less importance to the members of the Pacific Coast Electric Transmission Association than are those operating under high heads. The characteristic of a high head plant differing from that of a low head plant is that the penstock instead of being short, of large diameter and of low water velocity is long, of comparatively small diameter, with the water velocity rising as high as 12 to 15 feet per second. From this condition results that any attempt to regulate the wheels by varying the flow of water produces fluctuations in the pipe which are not only difficult to resist mechanically in pipe construction, but also are most disastrous to attempts at regulation, since the curve of efficiency of the high head water wheel varies much more rapidly from full load to one-quarter load than the curve of efficiency of the low head wheel; and furthermore, any attempt at closing the water gate at the end of a long pipe in which the water is flowing at a high velocity is resisted by the water within the pipe with a tendency to momentarily maintain the same energy without much reference to the size of the opening. The effect of varying the opening in the water gate is to vary the velocity of the water flowing through it, and, as the energy is equal to one-half the mass times the velocity squared, the variation of velocity tends to maintain a constant amount of energy imparted to the wheel in spite of the variations in the mass. In a station operating more than one wheel from the same pipe line, this effect is distributed amongst all the wheels running, and it is often possible by closing one gate partially to speed up all wheels for an instant, the wheels only attaining the proper speed due to the reduced opening after they have been subjected to a series of impulses from the surging water within the main pipe. In one case to which the attention of the writer was called, where wheels were operated under about 250 feet of head, closing of a single gate at the power house would cause the water to rise in the forebay as much as ten feet, which rise was necessarily occasioned by variations in pressure equal to about ten per cent. of the full pressure at the power house. Furthermore, it is hardly to be conceived that any throttling nozzle that has been devised can prevent leakage and prevent eddies of water on the back of the bucket producing disturbances of the speed regulation. In consequence of these facts, it seems to be the clear conclusion that regulation of high head wheels can be best obtained by a system which does not disturb the flow of water in the pipe line, which points either to the deflecting nozzle or the deflecting hood, and while we have no tests of the two systems which are thoroughly reliable, it certainly seems that the undistorted stream from a deflecting nozzle should give higher wheel efficiency at partial loads than will the distorted stream produced by a deflecting hood. If either of these systems is to be used the plant should be so installed as to reduce the wastage of water at partial loads as far as possible, since, of course, with a deflecting nozzle or deflecting hood, the flow of water through the nozzle is always constant. Such a sub-division, therefore, of the water wheel units is necessary as will allow cutting out of entire wheels when the load shall vary materially. It is not the desire of any engineer to install small generating units which this system of regulation seems to entail, but the same result can be obtained by a multiplication of the number of wheels attached to each generating unit. Up to the present time no more than two wheels per generator have been installed in any high head plant, though in certain low head plants as many as five or six wheels have been attached to one generator. Should high head plants be installed with as many wheels as this, the cost of the entire plant could be kept down by increasing the speed of the generators very materially. In fact, for units as large as 1000 kilowatts a speed of from 600 to 1000 revolutions should be readily attained and the cost of such a plant with five or six wheels on the generator shaft would not be greater than the cost of a plant with one wheel running at about 200 revolutions attached to a generator of the same capacity.

When we pass from the water wheel to the generator,

we find that while the water wheel must regulate for constant speed, the generator, which is operated at the constant speed of the water wheel, must be adapted for variable voltage regulation. In specifying generators it is far more common to demand extreme self-regulation as regards constant voltage than it is to demand a possibility of great voltage variation, whereas in the generating station the machine must necessarily be varied in voltage even though a constant voltage be demanded by the customer, and, in consequence, machines that are designed for self-regulation of constant voltage are not generally satisfactory in long-distance transmission plants. This is especially true on account of the fact that it is the custom authorized by the standardizing rules of the American Institute of Electrical Engineers to measure the regulating properties of the generator on a non-inductive load. A non-inductive load in a long-distance transmission plant is an impossibility, for even though the plant be used only when furnishing a non-inductive load, as of incandescent lights, the lines and transformers introduce at the generator a reactance which must be taken care of by the design of the machine. Indeed, the extremes of reactance are always encountered in such plants, since at low loads the long lines will make the generator current lead; at high load, they may lag very materially. In consequence of these facts, the inductive regulation of the generator as such must be as high as possible, though the ohmic resistance of the machine need not be necessarily low as would be the case for a close self-regulating machine operated on a non-inductive load; and many generators acceptable in power stations for the reason that under the conditions of non-inductive operation very close self-regulating properties, are unsatisfactory in long-distance plants; both for the reason that they will vary in voltage greatly when inductive loads are applied, and furthermore, they have not sufficient margin of field capacity to permit of over-excitation necessary for overcoming the effect of the lag factor. In consequence, the capacity of both the field and the armature must be higher than is commonly allowed, or else under the common circumstances of running, the machines will not be able to use within 10 or 15 per cent. of the full energy delivered by the water wheels. It is not often acceptable in long-distance transmission plants that the generators should have a possible voltage regulation equal to the full amount of the line loss, but they must be designed to permit from two to three times the voltage variation determined by the losses in the lines. It may seem anomalous to state in the beginning that the machines need not be designed for close self-regulation and in the end that their inductive drop must be smaller, but when it is remembered that close self-regulation may be produced by low ohmic resistance, which is unnecessary for small inductive drop, the anomaly is explained. A complete discussion of this effect was given by Prof. Cory last year before the Association.*

The same observations are true of the step-up transformers; this, also, having been called to the attention of the Association last year by the writer in discussion of the experiments at Stockton.* The only essential difference between the transformer effect and the generator effect being, that while the regulation of the generator on non-inductive load can be about one-third the regulation of the transformers on an inductive load, it seems to be impossible to design a generator better than about one-fifth as good regulation as the best transformers, though the writer's observations last year on transformers show that while a transformer designed for two per cent. non-inductive regulation may give a ten per cent. rise in voltage on a leading current, it has been found that transformers with the same non-inductive regulation can be designed to give a voltage rise, under the same conditions, not over one-quarter as great; and, furthermore, as the machine must compensate for the voltage regulation, both within its own coils and also within the coils of the step-up and step-down transformers, as well as throughout the whole line, it follows that the transformers should be designed to relieve machines as far as possible of great necessity for variation as the inductive effect of the load changes. In consequence, the specification of the inductive drop through a transformer is, in general, more important than a specification of the non-inductive regulation.

Perhaps the worst disturbing effect of all is to be found in the line itself. Here we have not only an inductive drop, but also a heavy capacity current, the capacity current remaining practically constant at all loads while the inductive drop varies with the load. The question for the proper disposition of the line to have the capacity current from the line counteract entirely the various reactances throughout the circuit, is a very alluring one and has been tried by many designers; but as the capacity current remains constant while the reactance continually varies with the load, it is impossible to so adjust the line in height above the ground a distance between wires as to effect any serviceable self-regulation. If self-regulation consisted in the maintenance of a constant voltage at a constant load, the line might be so designed as to aid in producing this effect, but as the load falls the importance of the leading current in the line becomes greater, while as the load rises its importance diminishes, in both cases disturbing the voltage and demanding from the machine a wide range of possible manual regulation. Until recently, the exact effect of the line as regards both capacity and inductance, proved to be a difficult problem presented for solution, though, of course, the solution could be accomplished by several methods on devoting a sufficient amount of time. This problem is one that has given the writer much labor, and it was with pleasure that in conjunction with Mr. F. G. Baum, he was able to present before the American Institute of Electrical Engineers this year a simpler solution for the regulation of a circuit for any character or changes of load, taking into account not only the questions of the load and transformers, but also the line. The line itself limits the amount of power that can be transmitted to a great distance, for the reason that for a line of about 100 miles in length, with voltage be-

*See page 57, Transactions of the Fourth Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, 1899.

Ibid, page 7.

tween 40,000 and 50,000, from 1200 to 1500 kilo-volt amperes must be used in charging the line—unless reactance coils are used—and, in consequence, an amount of power less than about 3000 horsepower cannot be satisfactorily delivered such a distance even where the selling price of power should be enough to counterbalance the cost of the line of such a length, the large capacity current making a question of any feasible system of regulation almost an impossibility with a smaller amount of power to be delivered.

By the use of reactance coils at the sub-station the generator current at no load can be made very small, and I believe it will pay to put in reactance coils on long lines, not only to reduce the generator current and line loss at no load, but as sub-station voltage regulators. If half the charging current be neutralized, the lower limit given for the power that may be transmitted over a 100-mile line will be reduced one-half.

I believe the proper way to regulate the voltage at the sub-station is by the use of adjustable reactance coils and a compensated voltmeter at the generating station. In any case, feeder regulators should be put on the feeder circuits, but no regulators on transformers, especially where two or more banks are operated in parallel.

Finally we come to the regulation within the sub-station. A sub-station must deliver voltages that are constant within short periods at the very least. The customer may demand a voltage variation on account of the losses within the distribution lines as his load changes, but during such periods as the customer's load remains constant, the voltages must remain constant. The fact that his voltage may change with his load demands some system of manual regulation within the sub-station, and while a possibility of varying the voltage at the sub-station on the customer's lines as much as 15 per cent. is in almost the extreme case ample allowance, the fact that the generator will necessarily alter its voltage with an alteration in the character of the load, irrespective of its size, it is not generally safe to install a sub-station system in which at least 25 per cent. voltage variation is not. in the extreme cases possible.

In this paper nothing very startling has been presented, but it is the writer's opinion that the following points are somewhat new and demand careful consideration:

1. The subdivision of water wheels and the use of extremely high speed machinery.

2. A wide range in the possible voltage variation in the generators, with generators and transformers both designed not for good non-inductive load regulation, but for good inductive load regulation.

3. Lines designed for the smallest possible capacity current without reference to any attempt at balancing the line capacity against the load lag.

4. The use of reactance coils at the sub-station—instead of regulator heads on transformers—and wide range of regulators in feeder circuits.

THE PRESIDENT. I don't suppose this paper can be the object of discussion, the author being away and not being able to answer. We have a paper by Professor Cory practically on the same subject, or very nearly the same subject, to be read later, and I propose that anything in that line be discussed after Professor Cory's paper.

PROF. CORY. The principal point that has been brought out in this paper—the question of the regulation on very long lines and the use of impedance coils—has received treatment in the shape of a concrete example by myself, and I think the discussion probably could very well come when that is taken up.

THE PRESIDENT. In that event, we will listen to Professor Cory's paper.

The following paper was then read:

TRANSMISSION SYSTEM REGULATION.

BY PROF. C. L. CORY.

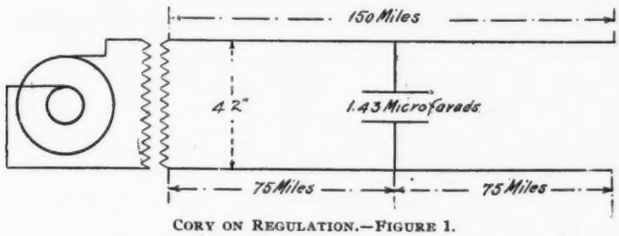
AT the present time the problems connected with the long distance transmission of power have assumed a different character as the distance of transmission has increased with a corresponding increase in the voltage. As long as the distance of transmission does not exceed 50 miles, and the voltage used is not greater than 25,000 volts, the capacity of the line does not introduce a serious problem in regulation. At the present time, however, we must consider the effect of the capacity of the line, particularly in distances approximating 150 miles. Last year in a paper presented upon "The Regulation of Alternating-Current Generators," a 10,000-volt, 500-kilowatt, 10-mile transmission was considered; in this case the effect of the capacity of the line was practically negligible.

In order to present the best illustration of the problems connected with the regulation on long-distance transmission systems, I have taken the conditions of a transmission of approximately 10,000 kilowatts over a distance of 150 miles terminating in San Francisco. This transmission is now being constructed by the Standard Electric Company of California. In practically every detail the data I have taken is from their work as it is now being installed. One slight difference from the assumed conditions should be stated, however, in connection with the length of transmission: the distance from the main power house to Mission San Jose is approximately 96 miles. From this latter point two branches are to be taken; one to San Francisco, the distance being 49 miles, the other line to Oakland, being on the opposite side of San Francisco Bay. The length of this line is approximately 26 miles. Notwithstanding this difference, the regulation of the system is practically the same as a straight 150-mile transmission.

The three conductors of the three-phase transmission are aluminum stranded wires three-quarters of an inch in diameter; the area of the conductors is 471034 circular mils. The maximum resistance of this wire per mile at 70° F. is .205 of an ohm; the frequency adopted is 60 periods per second; the distance between centers of conductors as placed on the insulators is 42 inches. In the following treatment of this transmission I have given some constants of the line which would result if the frequency adopted were 30 periods per second. These constants give desirable data in the comparison of the results upon regulation.

The inductance of the 150-mile transmission, or 300 miles of wire is .48 henry. The inductive reactance per

mile of wire, or one-half mile of transmission, 60 periods per second, is .634 ohm. This reactance would be reduced one-half, or .317 ohm if 30 cycles were used. The impedance per mile of wire, or one-half mile of transmission, using 60 periods per second, is .664 ohm; if 30 cycles were used, the impedance per mile would be reduced to .3775 ohm. The impedance factor of the line, or the



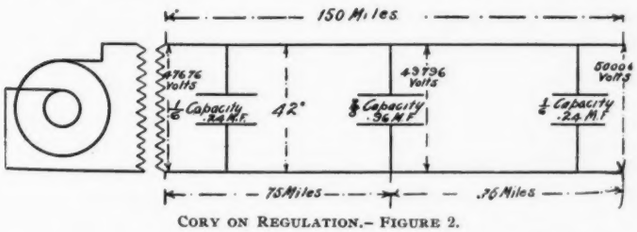
CORY ON REGULATION.—FIGURE 1.

impedance divided by the resistance, is 3.25, using 60 periods per second; if 30 periods per second were used, the impedance factor is reduced to 1.84.

Using a pair of conductors of the three-phase line as a convenience for computation, we find the resistance of 300 miles of line, or two wires of the 150-mile transmission, is 61.5 ohms. The inductive reactance of 300 miles of line is, using 60 periods per second, 190.2 ohms. The inductive reactance if 30 periods per second were used, would be reduced to one-half the above amount, or 95.1 ohms. The impedance of 300 miles of line, using 60 cycles, is 200 ohms; if 30 cycles were used this impedance would be reduced to 113.2 ohms.

In order to indicate the relation between the watt loss of the line in transmission and the voltage drop, we may consider that 10,000 kilowatts are available at the generating station at 60,000 volts. At unity power factor and with the three-phase system this would require 96.3 amperes per phase. In the 150-mile transmission the kilowatt loss would be 855.5, or 8.55 per cent. of the energy generated. Under normal conditions of operation the current in the line would be greater than 96.3 amperes, due to the lower power factor resulting from the inductance of the line and also from the inductive load.

The loss in volts per pair of wires in the 150-mile transmission, using 60 periods per second, would be 19260 volts; using 30 periods per second, the loss in the line would be 10901 volts; using 60 cycles, the per cent. voltage loss in the line is 32.1 per cent., while at 30 cycles

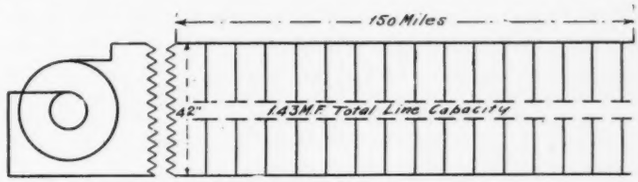


CORY ON REGULATION.—FIGURE 2.

the loss is reduced to 18.2 per cent. It should be remembered in connection with the volts drop in the line that using the three-phase system operating at unity power factor, only 87 per cent of the line drop is in phase with the generator voltage. Making this correction, the approximate voltage at the receiving end would be in the two cases 43240 and 50510 volts respectively.

In considering the capacity of the line and its effect, I have computed the capacity between two parallel cylinders 42 inches between centers, ¾ of an inch in diameter and each 150 miles in length. That the capacity of transmission lines is affected by climatic conditions and that we should consider the capacity between the conductors and the earth must be given consideration. As it is practically impossible to compute this capacity in the problem here considered, I have neglected this effect.

The capacity of the 150-mile transmission, as above stated, is 1.43 microfarads. The capacity per mile of transmission is .0095 microfarad. The capacity reactance between two wires per mile of transmission, using 60 periods per second, is 279000 ohms. If 30 periods per second were used the capacity reactance between two wires per mile of transmission would be twice the above amount, or 558000 ohms. Since this capacity reactance between wires decreases as the length of transmission increases, for the 150-mile transmission, using 60 periods per second, the capacity reactance between two wires is 1860 ohms. If 30 periods per second were used, this capacity reactance would be 3720 ohms. The charging current between two wires of the 150-mile transmission, using 60 periods per second, and 60,000 volts, is 32.25 amperes. This current is in quadrature with the electro-



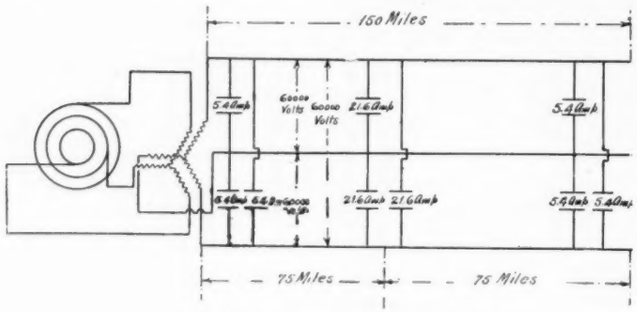
CORY ON REGULATION.—FIGURE 3.

motive force, since it is a capacity current, or leads the electromotive force by 90 degrees. This current passes between the two wires throughout their entire length. If 30 periods per second were used and 60,000 volts on this 150-mile transmission, the charging or capacity current would be reduced one-half, or 16.125 amperes. The volt-amperes, or apparent energy necessary to charge the line with the receiver circuit open is 3348 kilowatts, using 60 cycles and 60,000 volts. The real energy, however, is but 32 kilowatts. If 30 periods per second were used under the above conditions the volt-amperes, or apparent energy, is 1674 kilowatts, the real energy being but 16 kilowatts.

In order to show the effect upon the regulation in the above system I have assumed as a simpler illustration a 150-mile single-phase transmission, using 60 periods per second and a pressure of 50,000 volts maintained constant at the receiving end. In the above three-phase transmission we have approximately 3000 kilowatts per phase, so that the illustration is practically the same as regards the amount of power transmitted and its relation to the regulation.

Where the capacity effect of the line is comparatively small, for methods of computation, one condenser may be

assumed as being inserted in the middle of the line. For longer lines and higher voltages, however, the best approximation is to consider the line as shunted at the generator and also at the receiving end by two condensers of one-sixth the line capacity each. In the middle of the line a condenser of two-thirds the line capacity is inserted. In Figure 1 we have the representation of the first approxi-

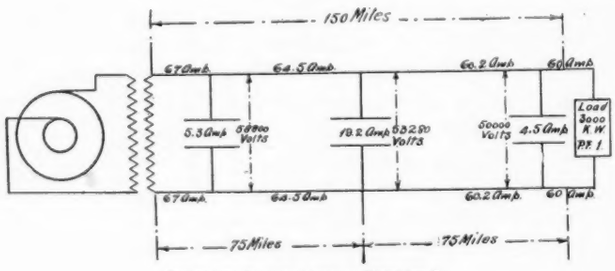


CORY ON REGULATION.—FIGURE 4.

mation. Figure 2 represents the second approximation which was used in deriving the results given below. Figure 2 shows also the effect of the capacity of the line in raising the voltage at the receiving end above the voltage at the generator when the load is very light. At the receiving end on open circuit the pressure is 50,000 volts, the generator pressure being but 47,676 volts. It is well to note here that a long transmission line should never be started up with the receiver circuit open. The charging current is excessive and this rise in voltage is a serious problem in insulation. Figure 3 represents the capacity as it is really distributed along the line.

Figure 4 shows the three-phase transmission and the quantity of charging current passing between the wires at the two ends and in the center, using the approximation above mentioned. It should be remembered that in reality this current passes between the two wires uniformly throughout their entire length, but the above approximation facilitates in computing the results.

Figure 5 shows the current in various portions of the line when 3000 kilowatts are delivered at the receiving end at unity power factor with a pressure of 50,000 volts. The current required in this case is 60 amperes. The



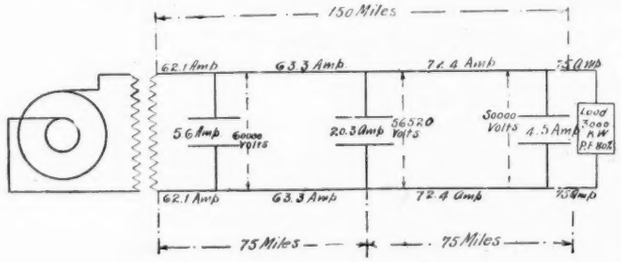
CORY ON REGULATION.—FIGURE 5.

current through the condenser at the receiving end is 4.5 amperes. When this condenser or charging current, is combined at right angles with the 60 amperes load current the result is 60.2 amperes. In the middle of the line the pressure is 53,280 volts and the resulting charging current 19.2 amperes. Combining again the charging current with the power current we have as a result 64.5 amperes. Finally, the voltage at the generator is 58,800 and the total current 67 amperes. The watt loss in the line is practically 10 per cent. or 302 kilowatts.

The particular point to be borne in mind in the case considered is that while the charging current at no load is more than 50 per cent. of the full load power current, when the load is thrown upon the receiving circuit the resulting current is but 11 per cent. greater than the required power current. This is a further illustration of the advantage of closing the switches of a long-distance transmission only when there is a load upon the receiver circuit.

Figure 6 represents the case of 3000 kilowatts delivered at the receiving end at a power factor of 80 per cent.

At 50,000 volts the current required is 75 amperes. The power current, or current in phase with the electromotive force, is but 60 amperes. The inductive current, or current at right angles to the electromotive force, is 45 amperes. This 45 amperes inductive current is to a very large extent neutralized by the capacity of the line, as the capacity, or charging current, is approximately 32 amperes. It would perhaps be best to say that the charging current is neutralized by the inductive load. The current through the condenser at the receiving end is 4.5 amperes. This current, combined with the 75 amperes required by



CORY ON REGULATION.—FIGURE 6.

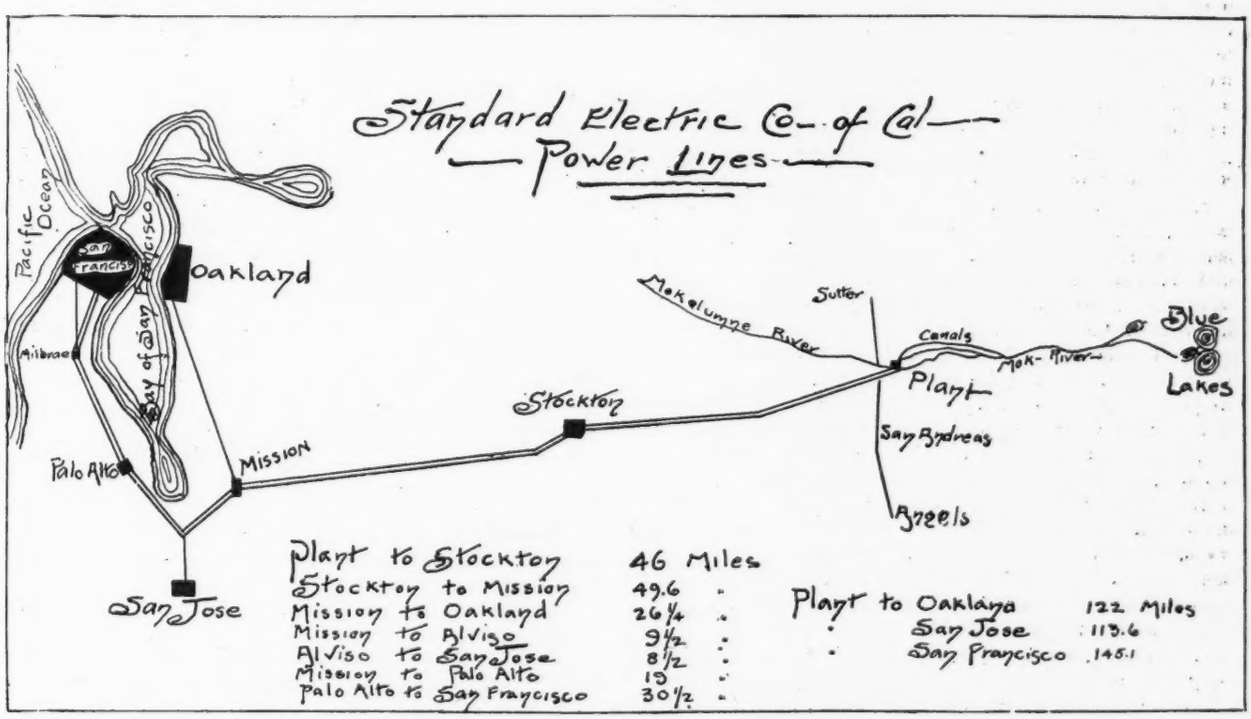
the load, results in but 72.4 amperes line current from the center to the receiving end. The pressure in the middle of the line is 56520 volts and the charging current 20.3 amperes. As before, this current is at right angles to the electromotive force, and when combined with the 72.4 amperes reduces the line current to 63.3 amperes. Ultimately, the current in the generator is reduced to 62.1 amperes, the pressure at the generator being approximately 60,000 volts.

Since the above results are derived by using an approximation it must be remembered that the reduction in current along the line in the latter case is a gradual one, the 75 amperes at the receiving end being reduced uniformly along the entire length of the line to 62.1 amperes at the generator. The approximation of the three condensers gives practical results and is therefore used.

It is evident from the above illustration that for very long lines we must have a method of producing inductive current to neutralize the capacity or charging current. The best way this can be done is with the use of induction motors, not alone at the end of the line, but throughout

the entire length of the transmission system. Artificial regulating impedance coils may also be used, but under most circumstances a lowering transformer is necessary. By using these artificial impedance coils the voltage and current may be regulated at all loads. The use of induction motors, however, seems preferable in most practical transmission systems. One condition which must be avoided is a sudden reduction of load at the receiving end. The invariable result would be a large increase of charging current and an abnormal rise in voltage at the sub-station.

In conclusion, it must be said that the conditions of the above illustration are extreme. The use of such a high voltage is largely responsible for the excessive charging current. The increased length of line results in a corresponding increase in capacity effect. Any increase in frequency likewise will result in an increased charging current in a direct ratio.



CORY ON REGULATION.—TRANSMISSION LINES OF THE STANDARD ELECTRIC COMPANY OF CALIFORNIA.

MR. POOLE. It would seem that Professor Cory's paper develops the fact that there is still a place for induction and synchronous motors, and it would seem to indicate that in the long transmission line with large capacity effect you couldn't afford to run without induction motors. In reference to the reactance coil mentioned in Dr. Perrine's paper, I think it was the intention to use those reactance coils only at the time of starting; that is to say, the motor would have a longer raise, undoubtedly owing to the capacity if the circuit were started up on no load, and adjustable reactance coils seem to me to be a very desirable thing until the load is thrown on. Then induction load, such as induction motors, etc., would naturally take care of the other parts, and it would seem as though it was a very nice thing to balance up, and each condition would have to be figured out especially for itself.

MR. LIGHTHIPE. I think this whole question has brought out the fact very prominently that the engineer in charge of the distributing circuit would practically have absolute control of just what is going in. For instance, we already know that the synchronous motors have certain uses in regulation. It was also brought out very prominently this morning that the induction motor or the impedance coil is an actual necessity. I think we are drifting into the realization of the fact that the engineer in charge of laying out distributing lines will have to have absolute control of the apparatus his customer is using. If there are to be a few synchronous motors on the system, he must handle them. The fact is, I think, to be brought out very strongly that if Smith has a synchronous motor and his neighbor has one, they will interfere with each other. I think the place for the synchronous motor is in the power house or adjacent to the power house where it can be kept under perfect control—in a sub-station if possible. The same is true of induction motors. The engineer has got to lay out his lines so that he will have control of his induction motors. If he has not enough induction motors running on loads he will have to put in impedance coils, and it is a matter of careful study, I think, for the station engineer to lay out distributing lines to get certain effects that he has got to attain. I think Prof. Cory deserves the thanks of the Association for bringing out these points so clearly in regard to the capacity effect on the line, and also the effect of an inductive load. The power current and capacity current put together in quadrature don't make very much difference at the power end.

I would like to ask a question in regard to the capacity between the three wires of a three-phase circuit and the earth. Take, for instance, the Southern California power plant with 33,000 volts between the outside wires; 19,000 volts between each of the wires and the middle of the Y. Immediately after our trouble there in starting up, we grounded both ends of the middle of the Y, and, I think, materially cut down the capacity.

PROF. CORY. In answer to Mr. Lighthipe's question I would say that I think it has been demonstrated—I don't suppose anyone here knows it more clearly than does Mr. Lighthipe—that the capacity effect on a transmission line is subject to very wide variations due to changes in climatic conditions. In order to avoid those changes as much as possible, I considered only the capacity between the cylindrical conductors and neglected the capacity between all the wires taken together and the earth, or any effect of that capacity. That undoubtedly would make things a little more serious, and, as you found there, it solved a very great part

of the difficulty by removing the effect of that capacity by grounding the center of the Y.

There is one point I forgot to mention, and that is that of course the ideal way to eliminate our capacity effect would be to put just as many impedance coils across the line as we have little condensers as shown here. In other words, take the actual condition of affairs: We have an infinite number of very small condensers in parallel along between the two lines; we could neutralize their effect at all loads, and it would not bother us in the least if we could put in parallel with each condenser a small impedance coil. That is out of the question in transmission work; it is impracticable under any circumstances. We are approximating this ideal arrangement when we use induction motors at the receiving end or distributed along the line of transmission.

MR. LIGHTHIPE. Doesn't that bring out quite prominently the fact that in a long distributing line the more customers we have who use induction motors for pumping, the better the effect on the line? Take, for instance, Southern California. There was a time there where they were tied into the Redlands company so that it made one circuit of the two systems. Practically, we have motors distributing all the way from Redlands into Los Angeles, for Colton has tapped off; Pomona has tapped off, and the new line running down to Santa Ana practically taps off in a different direction; then Pasadena taps off and the line continues to Los Angeles. I think the fact of distributing all the way along these long lines tends to reduce the capacity effect materially. I might say in the Southern California line the capacity effect was never strongly noticeable and never troublesome at all.

MR. BABCOCK. Professor Cory has mentioned the Stockton experience, and it might be of interest to know what happened there when we started up last year. I am sorry I have not my notebooks here because I have very complete notes of it; but to the best of my recollection it was something like this, though I will not vouch for the figures exactly. I was at the Stockton end the night that we first put the current into the line. (I shall speak now in terms of the distributing line voltages. The transformers were practically 10 to 1 ratio.) The voltmeter scale reads 250 with a 10 to 1 transformer. It ran to 2200, and I expected to see it stop there, but it went to the upper end of the case and I ran to the telephone, called the power house and told them to stop. Doctor Perrine wanted to know what the matter was and I told him we had gone off our scale, that I didn't know how far it had gone beyond, and that he had better stop. As near as I can remember, when they had 2200 at the station we had about 2580 at the Stockton end, which was an increase of practically 400 volts.

MR. LIGHTHIPE. What was your load on the Stockton end?

MR. BABCOCK. We had nothing on the line; I say nothing; we simply had transformers and the board. With open line. the current in the machine ammeter was 60 per phase. Then we cut in the transformers, and it dropped to 45 at the generating end. We got just fairly running and one of the transformers burned out, which ended the performance for that night, except we had a very pretty arc when I pulled out the 25,000-volt switches.

PROF. CORY. Don't you know it was more than 25,000?

MR. BABCOCK. I say 25,000; it was over 25,000—there is no doubt about that. During the time of the rewinding of the transformer and getting it into shape we had a chance to discuss the matter, and we saw no immediate solution; there was no available apparatus, and it became a question of running the Stockton end on one generator from the Blue Lakes end. Then when we added the Stockton Gas and Electric Company's synchronous motors the current was up about 50 or 55 on friction load. But they were limited in regulating capacity by this: that owing to some cause which was a matter of controversy, and I think we better leave it alone, they were taking an abnormal current. These motors when run light—a friction load—should take from 3 to 4 amperes, were taking all the way from 8 to 10 and sometimes 10 to 11, according to line conditions, and we could not correct it, so that a motor which should run normally under a load of 22 to 26 amperes was actually taking 33 to 35, and so it ran until we got our system regulated. There was a great deal of work done on those motors, trying to bring the current down where it belonged. Mr. Lighthipe and I worked three or four days over it. Finally, Mr. Baum worked the thing out, and we brought down from the power house some of the old upright Stanley transformers, put on them only the secondary coils and left the high-potential coils off. They are rectangular in section, ten inches on a side and four feet high. In place of building up the four sides we built up only three sides and put the fourth side in a wooden frame so that we could adjust the air gap. The practical result was that when those coils took about—that is, when we adjusted the air gap until they took, I think, 33 amperes, the voltage dropped immediately, so that we could run the Stockton circuit in multiple with Mother Lode circuits. The synchronous motors next door in place of taking from seven to ten amperes running light, took what they should have taken: two and three. In other words, there was a complete solution, practically, of the problem. Now, what took place when the Sperry motor went on? When the motor was first thrown on it pulled the voltage down to 1500. At the sub-station it would drop from 2400—well, I have seen it go to 1400, owing to the different positions of the converter on the first start. But we stood by the reactance coil switches, and as the load was thrown off the water rheostat which was used to start with, and into the motor, we cut out these coils so as to raise the potentials as high as possible. When the Sperry motor was running, as Professor Cory said, we did not use the inductance coils at all; but there were times—one occasion particularly—when the Sperry motor was cut out without warning us, and there were lively times at the power house. The voltage ran away up. The point I wish to bring out is this: that the practice in the Stockton sub-station and at the Blue Lakes station bears out precisely the hypothetical case which Professor Cory assumed; the results showed identically that the practice followed his theory.

There was one point I wanted to ask Professor Cory. In making calculations on your capacity current you took a single-phase line. Is that the proper method of calculating the capacity of a three-phase line? You took a single-phase circuit, with the same voltage and same distance between wires.

PROF. CORY. It does not make any difference how many wires there are. Suppose we consider two wires of a three-phase circuit. We have the capacity between these two wires, and if the voltage is 60,000, we get for the 150 miles of transmission 32.25 amperes capacity or charging current passing between the two wires. At 60,000 volts three-phase, 96 amperes per phase is 10,000 kilowatts at the generator. 9000 kilowatts on the receiving end would correspond to 3000 kilowatts per phase.

In order to simplify the discussion of capacity or charging current, I have assumed a 3000-kilowatt, single-phase transmission. The current required if we have 50,000 volts at the receiving end is 60 amperes at unity power factor. However, we still have the 32.25 amperes charging current. If you choose to convert this single-phase into a three-phase system, it is only necessary to multiply the single-phase line current by 1.73. The correct way, therefore, to compute the capacity of a three-phase line is to determine the capacity between each pair of wires. The point that Mr. Lighthipe brought out is also important: the effect of the capacity between the three wires taken together and the earth. In the computations I have made, this capacity is not considered.

MR. BABCOCK. The reason I asked the question is this: I could not make the charging current on the Stockton line agree with the calculated current. No matter how it was considered, it was simply a two-phase line; but no matter how we considered it, there were some unknown constants coming in which entirely vitiated all calculations on that line as compared with the observed charging current. I am perfectly well aware that in making that statement I am going contrary to other statements that have been made about that line, but I am prepared to stand by them. I don't call it a practical agreement when you say that the theoretical agrees with the observed and it agrees within 20 per cent.; I say your theory is not much account.

PROF. CORY. The only way you can compute your theoretical charging current is to assume a perfect sine wave of electromotive force. Any variation from a sine wave is going to increase the charging current, because all irregularities in our wave form give the effect of a higher frequency. Higher frequency causes a larger charging current. From the statements made about the Stockton line at the last meeting the capacity changed very much with different climatic conditions. I think it was said at the last meeting—at least I believe it is in the proceedings of the last meeting—that the capacity of the Stockton line would vary from $\frac{35}{100}$ of a microfarad to as much as $\frac{9}{10}$ of a microfarad. There has been a question about some typographical errors in reporting that particular matter.* An important point in this connection is that the magnitude of the charging current is much more important to determine than the capacity of the line. Therefore an actual measurement of the charging current under operating conditions is of more value in every way than the computation or determination of the capacity of the line.

MR. BABCOCK. I think that is a good criticism on what I said. My only object in making the calculations on the line was to see how far the published methods of calculation would agree with what we found. I have Professor Cory's feeling about the value of going into theoretical things when you are concerned with practical things; though it is Professor Cory's business, if I may say it—or it has been—to consider one side, and my business is to consider the other. As regards the capacity of the line under different conditions, the charging current was measured—I think I am right in saying this—almost entirely by a Rowland electrodynamometer. I have not had much experience with that animal, but I have had enough to show me that you can get almost any results you please from similar conditions. The measurements that were made outside of that were made with a hot-wire ammeter in the high-potential line, and I would go a good deal further on a measurement made by the ammeter in the high-potential line than I would with any dynamometer or instrument of that kind, especially in a case where the instrumental errors were not thoroughly investigated. In the case under discussion this was not done until long after the measurements in question had been made.

MR. HUTTON. Suppose we consider a three-phase line; suppose that we had 60,000 volts between all three of the wires when they were cut in. Suppose we cut in simply two switches, cutting in two wires, and we have a given charging current on the two wires. Suppose that a third switch is thrown in, and the third wire is cut in; what would be the ratio of this current in the second case to what it was in the first case?

PROF. CORY. The point is this: Suppose we close two switches of our three-phase line and leave the third one open. We then have the capacity between the two charged wires, and also the capacity between the dead wire and each of the two charged wires. We have two distinct capacity effects; we have capacity between each one of the live wires and the dead wire, and the capacity between each one of the two live wires. If we close the third switch we have then the capacity between pairs of live wires. What the ratio would be between the charging currents under the two conditions as shown above it is impossible to say. It would largely depend upon the insulation and location of the third or dead wire.

MR. HUTTON. Suppose the line were higher up from the earth so that the capacity of the earth had no particular effect on it, and the wires were perfectly insulated. Even though it were dead, would that affect the charging current?

PROF. CORY. I think it would.

MR. HUTTON. I made some measurements to determine the charging current on the 62-mile line of the Yuba Power Company where their line comes into the station at Sacramento. There were two circuits, six wires in all, arranged in this manner (illustrating): *A B* and *C* were the three wires of one three-phase circuit, each wire at the angle of an equilateral triangle; *A′ B′* and *C′* were the three wires of the second three-phase circuit, each wire at the angle of a second equilateral triangle placed over the first. It will be noticed we go from *A* to *B* to *C*, clock-wise, while from *A′* to *B′* to *C′* anti-clock-wise. The distance between the two wires *A* and *A′*, *A′* and *B*, *B* and *C′*, *C′* and *C*, *C* and *B′* and *B′* and *A* is 24 inches. The voltage was 20,000 and the frequency 63 cycles per second. Insulation of the line was one megohm.

An ammeter was placed in *C′* and the charging current measured in it under the following conditions, the line being open at the receiving end, current being supplied from the Sacramento station:

Switches in *C′* and *B′*	closed;	charging current in *C′*	4.25	amp.
" *C′*, *B* and *A*	"	"	"	5.2	"
" *C′*, *B′*, *A* and *C*	"	"	"	3.85	"
" *C′*, *B′*, *A′*, *C* and *B*	"	"	"	4.4	"
" *C′*, *B′*, *A′*, *C*, *B* and *A*	"	"	"	5.2	"
" *C′*, *B′*, *A′*, *B* and *A*	"	"	"	6.	"
" *C′*, *B′*, *A′*, and *A*	"	"	"	5.6	"
" *C′*, *B′* and *A′*	"	"	"	5.2	"
" *C′* and *B*	"	"	"	4.25	"
" *C*, *B* and *A*	"	"	"	5.2	"

It is noticeable that when the six wires are all connected in—that is, two live circuits complete—the charging current is 5.2 amperes, the same as when either circuit alone is in—either *C′*, *B′* and *A′* or *C*, *B* and *A*. Also we seem to get the same charging current in *C′* with *C′* and *B′* in as with *C′* and *B*—4.25 amperes in each case.

PROF. CORY. If we have two three-phase circuits on one pole and one is a live circuit and the other a dead circuit, the capacity effect on the live circuit will be greater than if we had but the one live circuit on a pole.

MR. HUTTON. That may be what makes the readings so close together, on account of the second dead circuit consisting of four wires instead of two.

PROF. CORY. The best plan, I should think, would be to make a measurement of the charging current on the two live wires. Then, after binding the other four wires together and grounding them, make a second measurement of the charging current on the two live wires.

MR. BABCOCK. Would that condition still be true if you had your wires arranged in this hexagonal form—two triangles?

PROF. CORY. No, I think not. When the system is a balanced one that disposition of wires eliminates largely this cross effect.

MR. BABCOCK. You could eliminate by that arrangement?

PROF. CORY. Yes, if the system is balanced.

MR. BABCOCK. There was one further question I wanted to ask. On the Stockton line last year we had barbed wire over the main line. The arrangement of wires was not on a square, but on a parallelogram. One side was 41 inches and the other side 24 inches. The phases were in the usual form, diagonally arranged. The question always has been, what effect did that ground wire have on those two circuits as regards capacity? Did you ever work that point out?

PROF. CORY. I am sure I never did. Your barbed wire was connected with the ground?

MR. BABCOCK. It was connected with the ground every fourth pole.

PROF. CORY. I should think Mr. Hutton's explanation would cover that, that it practically brings the earth's potential up to the wires.

MR. BABCOCK. Very true. But when you calculate what ought

*Transactions Pacific Coast Electric Transmission Association, 1899; pages 9, 10 and 12.—THE EDITOR.

to be the charging current, considering the earth up there, it doesn't help us out at all.

PROF. CORY. But that wire has not the surface of the earth; it has just the potential.

MR. MCADIE. I want to ask Professor Cory if he has made any experiments, or if he knows of any experiments on this coast having been made, showing the relation between the atmospheric conditions and the impedance of the system with varying frequencies. And then again, if I understood him rightly, he stated that the old Ferranti effect was something that was to be avoided if possible, and he alluded to the case of mains lying together in earth and increasing the induction. Was that not the case? Wouldn't that happen in the case of the low fog lying through much of the country through which these mains must run? Would not that increase the capacity and lead to an increase of the potential at the far end of the line—a high potential at the end of the line and at the generator?

PROF. CORY. What I meant to bring out was that the reason the capacity was so much greater in the Ferranti cables was not essentially because they were in the earth, but because the two conductors were separated by gutta percha and mica, whose specific inductive capacity is about three times that of air. Also the Ferranti cable was a concentric one; one conductor consisted of a hollow cylinder inside of which was placed the other conductor, a solid cylinder. The insulation was placed between the two conductors. In every respect it was as perfect a condenser as could be made, and the results were serious at the receiving end of the line when the switch was closed at the generator with no load on the line.

Regarding your other question, about the effect of fog, I am sure I don't know. I think perhaps some of the others here have had actual experience in atmospheric conditions and can answer that. I know this: that when you try to make measurements on a transmission line, using delicate laboratory instruments, you might just as well quit to begin with, because the long lines are charged with atmospheric electricity. It is in the same condition which makes it possible to send telegraphic messages without any battery. The battery current is a very small fraction of these induced currents, either from atmospheric changes or other causes. The best thing to do is as Mr. Babcock says—get some good commercial instruments and make measurements, using the line current, perhaps.

A fog would be a straight resistance. It would be a case of actual transferred electricity from one conductor to another, through the fog, or leakage.

MR. POOLE. There is one point in connection with Professor Cory's remarks. It would seem that the capacity current on a 10,000-kilowatt system would require approximately 3000-kilowatt capacity in amperes before you could start the system. Is that right?

PROF. CORY. No, not if you use impedance coils and cut down the charging current.

MR. BABCOCK. That is, if the system were left open, and you wanted to charge your line, it would require a capacity of 3000 kilowatts or burn your machine out?

PROF. CORY. Perfectly right. Here is our machine operating at unity power factor. 10,000 kilowatts requires 96.3 on each wire at 60,000 volts. If we should close our switches on the open line the current demanded from the generators would be 32¼ amperes across each pair of wires. We would get 1.73 times 32¼ amperes in each wire. This 32¼ amperes charging current at 60,000 volts passing between each pair of the three wires, represents only 32 kilowatts in actual C^2R loss, although, as has been said, the apparent kilowatts would be approximately 3000.

MR. SINCLAIR. Professor Cory said that the nearest approach to the highest theoretical conditions on that line would be brought about by a series of impedance coils scattered along the line as shown in Figure 3. In view of what he said concerning the effect of induction motors on the end of the line, wouldn't you approach as near as possible to that highly theoretical condition by scattering a number of induction motors along your 150-mile line?

PROF. CORY. Certainly, as Mr. Lighthipe has said.

MR. SINCLAIR. What would be the result if, instead of scattering induction motors along your line, you scattered synchronous motors along the line?

MR. LIGHTHIPE. It would be worse.

MR. HUTTON. Under-magnetizing them would be all right.

MR. SINCLAIR. What I am getting at is, isn't it advisable in a transmission of that kind to avoid synchronous motors and seek for induction motor work?

PROF. CORY. Yes, that is the correct conclusion, particularly on very long lines operating at a voltage of, say, 60,000. If we reduce the voltage to 40,000, your charging current is but two-thirds what it would be at 60,000 volts; as the length of line decreases, the charging current decreases proportionately. Also, as the frequency decreases, the charging current decreases proportionately.

MR. SINCLAIR. I am taking the conditions you speak of—a 150-mile line under 60,000 volts, using 60 cycles.

PROF. CORY. Under such conditions I think I would hesitate a little about putting very large synchronous motors along my line unless I had some way to lower my power factor in each place. I would rather, if I could, have some induction motors to help lower the power factor. In other words, as was said about a synchronous motor, you can operate it three ways. You can make a condenser out of it; you can operate it as if it were a straight resistance, or you can make an impedance out of it. What we want, as I have tried to bring out, is impedance. We don't want a condenser. If we get an over-excited field on the synchronous motor we are making it still worse. But what we must do is to weaken the field. When we weaken the field we are not making the best operative conditions for our synchronous motors.

MR. SINCLAIR. In Doctor Perrine's paper on regulation he made the statement that it was not practicable to attempt to operate a line 100 miles long unless you were prepared to transmit at least 3000 kilowatts, and that was due to the capacity in the line. Do I understand that Professor Cory's statement bears that out, that it is no use to consider—I am not speaking of the commercial point, but electrically—that it is not of any use to consider a 100-mile transmission, and there is no way that you can operate it unless you have at least 3000 horsepower to start with?

PROF. CORY. I hesitate about taking opposite sides to anybody not present. I should say, however, that it is not true.

MR. SINCLAIR. It impressed me strongly at the time, and I made a note of it.

PROF. CORY. I think the point Doctor Perrine had in mind is what I brought out: that to charge that line, using a three-phase system at 60,000 volts and 60 cycles, would require 3000 apparent kilowatts. But you see, we must not stop there. You can have 1000-kilowatt capacity if you want on the generator end of your line, or 500 kilowatts, even, provided you start your plant up right. That is the point—neutralizing your capacity or charging current with impedances.

MR. LIGHTHIPE. The whole point is that you must not start your line empty. You have to have your impedance in before you close your main switch.

PROF. CORY. Exactly. Suppose you have a 1000-kilowatt plant, and you attempt to start it up without anything on the other end; you have an immediate demand on your plant of three times the amperes it is able to give.

MR. SINCLAIR. But it is so easy to regulate that.

PROF. CORY. Perfectly so. Put an impedance coil in the receiving end of the line, and when the regular inductive load comes on take it out.

MR. HUTTON. Last year we had a paper from Mr. Jones, and he made a suggestion that as the pressures were gradually crawling up, we might get to a point where we would have to have three pole lines and a set of insulators on each one to carry three wires. Wouldn't that be one method of getting rid of some of the capacity effect.

PROF. CORY. Yes. But your self-induction is increased the

wrong way. Just as soon as the distance between wires is increased by having three pole lines, say 200 feet apart, we are doing the same thing as if we were putting impedance coils in series with an ordinary line. We want them in parallel across between the wires. Your capacity would be all right, but the self-induction would be so great that at ordinary frequencies the impedance would be many times the resistance of the line.

Communicated after adjournment by Prof. Cory:

From the measurements made by Mr. Hutton, we have the charging current on a 62-mile line, using 60 cycles and 20,000 volts, to be 4.25 amperes between two wires. The disposition of the two wires was such that the capacity per mile would be about the same as the Standard Electric Company's line.

The 150-mile line would be 2.42 times as long as the 62-mile line. For the same voltage, therefore, the charging current would be 2.42×4.25 amperes at the same voltage. At 60,000 volts, the charging current would have been $3 \times 2.42 \times 4.25 = 30.85$ amperes. This is practically the same as the computed charging current, as shown in the paper, or 32.25 amperes.

The following paper was read by the author:

APPLICATION OF STORAGE BATTERIES TO TRANSMISSION SYSTEMS.

BY C. O. POOLE.

THE term "electric storage battery" is misleading to a great many; it does not, as the name implies, store electricity directly. A form of chemical energy is stored and as a result of chemical reactions electrical energy is given off. The exact reactions that take place in a lead accumulator during a cycle of charge and discharge are as yet imperfectly understood, and even the results of the reactions are somewhat in doubt. It was generally believed until within the last few years that the composition of the active material, when the plates were fully charged, was lead peroxide ($Pb O_2$) on the positive plate and spongy lead (Pb) on the negative plate; on being discharged, the peroxide of lead on the positive was supposed to be converted into lead monoxide ($Pb O$), and the spongy lead of the negative plate was also supposed to be converted into lead monoxide the same as the positive plate—simply transferring an atom of oxygen from the positive plate to the negative plate. On charging, the process was supposed to be reversed—an atom of oxygen leaving the negative and appearing on the positive plate.

The latest accepted theory, however, differs materially from this. Investigators have proven quite conclusively that lead sulphate is formed directly on both plates during the discharge; the positive plate starting from lead peroxide and the negative plate from spongy lead; the positive plate losing an atom of oxygen and the negative gaining an atom of oxygen. Two atoms of hydrogen sulphate are taken from the electrolyte and combined with an atom of oxygen at each plate, forming sulphate of lead ($P B S O_4$). During the process of charge this action is reversed, the lead sulphate being reduced and the plates assuming their former condition; the hydrogen sulphate combining again with the electrolyte and raising the specific gravity of the cell. The specific gravity of the electrolyte is a certain indication of the condition of the battery. The specific gravity increases in direct proportion to the charge, and this fact offers a means of telling at all times to just what extent the cell is charged rising on charge and falling on discharge.

It is not my intention to tire you with the detail working of a battery, but I could not refrain from saying a few words on that very interesting subject—the theory of the lead accumulator. It differs so widely from any other piece of electrical apparatus that some explanation seemed necessary before applying it to our subject.

The storage battery during the last few years has made rapid strides to the front and there is scarcely any branch of the electrical industry that has not found it a valuable adjunct, and in many cases it has become almost a necessity.

Three of the most important points that confront the central station manager, and without which success is seldom attained, are good regulation, an uninterrupted service and a good load factor—all three of which the storage battery assists very materially in securing. A few years ago an incandescent service that could be kept within 15 or 20 per cent. was considered very good; and if it did not go out two or three times a night the customer would wonder what the trouble was. Today, however, the conditions are changed; the public has been educated to good service and will be satisfied with nothing else.

The word "load-factor" we will define as the average height of the load line as compared with the area enclosed within a parallelogram formed by drawing a line across the peak of a daily load diagram, using the base of the diagram for the other line. A convenient way to obtain the area enclosed within the load line is to trace the line with a planimeter and the area thus obtained divided by the total area of the parallelogram gives at once the load factor. Figure 1 represents a typical load curve of a central station supplying light and stationary power. The position of the peak varies with the seasons of the year. During the summer months the peak comes at 8 p. m., while in winter the maximum peak of the year comes about 5:15 p. m. The reason for this is obvious. During the long days of summer very little artificial light is used in a large percentage of business houses and factories, owing to their closing in the evening before it grows dark. The peak at this season of the year is known as the theatre peak, and is the result of theatres and other public places of amusement opening at that time. During the winter months it becomes quite dark between 5 and 6 o'clock, and all business houses and factories use light quite extensively before the motor load is thrown off. In this way the lighting load overlaps the motor load, thus making a combined peak. Sometimes the difference between the summer and winter peaks amounts to as much as 50 per cent.

It will be seen at once that apparatus must be provided to carry the maximum load of the year and it is a common thing in steam generating plants to see thousands of horsepower in boilers, engines and generators lying idle for ten months in the year, and during the two months that they are pressed into service it is only for two or three hours

(Continued on page 15.)

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VOLUME X JULY, 1900 NUMBER 1

EDITORIAL.

ELECTRICITY AS A BY-PRODUCT.

Almost coincident with the publication of the last issue of the JOURNAL appeared a paper by H. T. Yaryan on "Hot Water Heating from a Central Station," as read before the American Society of Mechanical Engineers, Cincinnati, May, 1900.* In this paper Mr. Yaryan delineates to one of the principal engineering societies of the world the technical and commercial results which have followed from the experiment of the Toledo (Ohio) Heating and Lighting Company in the distribution of the heat of exhaust steam by its hot water system. By using water as a vehicle, the Toledo company is distributing heat from a central station over a territory measured by a radius of one and one-half miles from the station, and all with profit to the investors and entire satisfaction to the consumers. This has been done in Toledo for the past five years, a period sufficiently long to place the enterprise beyond the experimental stage and to entitle it to be classed as a successful business venture.

It seems at first to be almost incredible that a central station, built primarily for the generation of electrical energy, should be able to so develop the sale of heat realized from the exhausts of its engines that the revenues from electric service should become to be considered as earnings derived from the sale of a by-product, but nevertheless such is the lesson of the experience of the Toledo station. Moreover, gas engineering knows of a fitting analogy in its line, where the generation of gas is made a by-product to the manufacture of coke.

"I imagine," says Mr. Yaryan, "that there would be a sensation if some great genius like an Edison or a Tesla were to announce that electricity could be produced without cost, yet the business of the Toledo Heating and Lighting Company for the six months ending January 1st last shows (the load being 199 houses heated and 450 houses lighted) its receipts and operating expenses to be:

Receipts from heating	$9,900.88
Receipts from lighting	9,064.78
Fuel	$5,040.63
Wages and salaries	2,827.14
Expenses (taxes, repairs, oil, waste, etc.)	1,896.77
	$9,764.54

"I presume," continues Mr. Yaryan, "the question will be asked why electricity should be treated as a by-product instead of heat. My answer is that charges for heat can be fixed and maintained, the consumption of coal increasing proportionately with the number of consumers, while the opposite is true of electricity, and a flexible scale of charges is necessary if the large excess output is to be disposed of."

The Toledo system itself is simple. The steam boilers, engines and dynamos are such as may be used in any ordinary electric light station. Heaters of the tubular type, through which the water passes from the pumps to the mains, receive the exhaust steam from the engines, heating the water to any desired temperature. When more exhaust is being produced than is required for the water, the excess is delivered to a water storage tank to be used later when the output of electricity is small. The circulating system consists of two wrought iron pipes, laid side by side in the ground, protected by planks with air spaces between, one pipe being used for the outflow of of hot water impelled by the pumps, the other for the return water from the coils in the various houses heated, going back to the suction end of the pumps to be forced again through the heaters where the loss in temperature is restored. The company operates two stations, the length of the mains from the Floyd-street station being 8550 feet and the number of houses heated is 101, while the length of mains from the Twenty-second-street station is 8260 feet, the number of houses heated being 98. The total amount of radiating surface connected is about 175,000 square feet, and the estimated loss by radiation from mains is between fifteen and twenty per cent. This estimate is probably safe because the water reaches the extreme end of the mains, three-quarters of a mile from a station, in the coldest weather, with a loss of 12° F. As the water returns to the station with a drop of 35° F., this would indicate a loss of about seventeen per cent. in the ground—an average loss of six degrees occurring in the houses. Water enters the houses at 160° F. when the outside temperature is freezing, and the practice is followed of raising or lowering the temperature of water delivered to the mains one degree for each degree of variation in the outside temperature.

This heating system is in operation for about seven months of the year, and in order that the exhaust steam now going to waste during the five summer months remaining may be turned to profit, the company is now installing a refrigerating plant for domestic use to distribute cold brine in exactly the same manner as hot water is now distributed, but using a separate set of mains. An ammonia absorption refrigerating machine, operated with exhaust steam, will be used so that as the demand for

*Reprinted in the *Engineering Review* (N. Y.), Vol. XXXVI, page 504, May 16, 1900.

heat ceases, that for cooling purposes begins and thus will the exhaust steam be utilized all the year around. It is worthy of further note that hot water heating systems similar to that used in Toledo are also in operation in LaPorte, Ind., Mattoon, Ill., LaCrosse, Wis., Kenosha, Wis., Alton, Ill., Portage, Wis., and in Boone, Perry, Ida Grove, Iowa Falls and Mason City, Iowa.

All that has been said with reference to the utilization of exhaust steam in heating by the hot water system applies with greater force in the suggestion proposing the use of gas-driven central stations as outlined in these columns for June—with greater force because the amount of heat recoverable is greater with the gas engine than in the steam engine. California is without doubt of such a climatic temperament, so to speak, that it will offer but poor encouragement for pioneering in the line of heating systems, but it will watch the Toledo experiment in refrigeration with greatest interest, for in that direction, rather than in heating, are its central stations more directly interested. California is not the Pacific Coast, however, and it is not venturesome to hold that its northern sisters in statehood contain many steam plants that could be made to add handsomely to their earnings by the development of hot water heating distributing systems.

APPLICATION OF STORAGE BATTERIES TO TRANSMISSION SYSTEMS.

(Continued from page 13.)

per day. So it might be said that this peak apparatus is used about 90 hours a year. What is true of a steam plant in this respect is equally true of a water power transmission system. Obviously, the all-important question is how to increase the load factor. In their efforts to bring the load factor up, many companies offer special inducements in the way of low prices for the current during hours of light load; but the natural solution of this problem is the storage battery. Nevertheless, the storage battery has its limitations that become apparent when you receive notice from your banker that you have overdrawn your account.

It therefore is the high price of batteries that makes the manager hesitate, and he goes over his figures a second and a third time to be certain he is justified in making the investment. But once the battery is installed and put into service, then all fears of having made a mistake vanish. I have yet to find a manager who was sorry he had purchased a battery. They will all tell you it is worth the price paid if only for the improvement in regulation and the sense of security that it affords.

The load factor for the average central station without storage batteries is about 40 per cent., and to obtain this the day motor load must be quite considerable. The load factor of street railway systems is a little better than lighting systems, but it becomes a serious problem when street railway companies have to maintain an all-night service without a storage battery. If the storage battery is considered from a strictly economical point of view, it necessarily becomes peak apparatus. The width of a peak that can economically be cut off with a battery must be balanced by the price, efficiency and cost of maintenance of the battery against the conditions of cost of generation and transmission. With a steam plant the limit is about two hours; that is to say, if the width of a peak be more than two hours, it is generally more economical to install steam apparatus. With a water power system, however, the conditions may be such that a much wider peak can be taken with advantage. Take, for instance, a company having a large investment in its water system and its pole line, together with its numerous sub-stations, etc. The interest on this investment becomes a fixed charge, and the kilowatts at the end of the line must bear the burden of it. It becomes at once apparent that the greater the kilowatts delivered per year, the less will be the fixed charge per kilowatt. As the capacity of the plant is limited, the only way to obtain the maximum output is to run the plant at the full load continuously. As the average load factor of all classes of work is about 50 per cent., there is but one way to accomplish our object and that is to store the energy at time of light load and give it out on the system at time of maximum load.

For example, let us assume that we have a 6000-kilowatt plant transmitting 90 miles at 40,000 volts and, say, 10 per cent. line losses. Suppose the installation complete cost $1,115,000.* This included water system, power house, one extra generator, pole line, sub-stations, etc.

Interest on this amount at 6 per cent. will be	$ 66,900
Per annum, allowing 7 per cent. for deterioration and repairs	78,050
Operating expenses	40,000
Making a total fixed charge per annum of	$184,950

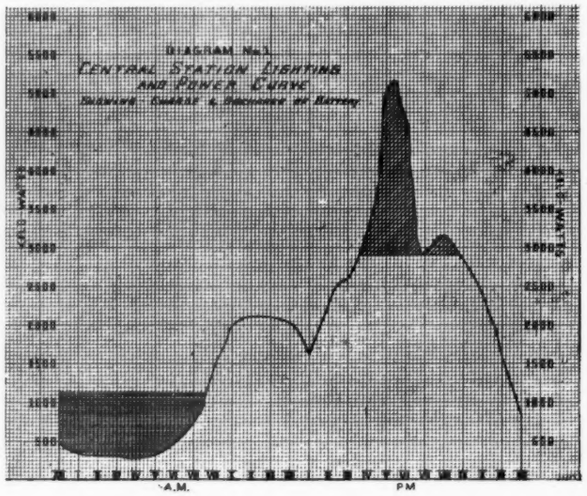
Assuming now that we have a load curve calling for a maximum of 6000 kilowatts, which is the capacity of the assumed installation, then with a load factor of 50 per cent., the total kilowatt-hours delivered per annum would be 26,280,000 and the fixed charge per kilowatt-hour would be $\frac{7}{10}$ths cent.

Let us now examine the character of the load with which we will deal. Figure 1 is a curve taken from a representative Edison central station in one of the Eastern cities and shows a winter peak. The plant is provided with a large storage battery and the shaded portion of the peak shows how the battery takes care of it. The horizontal shading between the hours of midnight and 7:30 a. m. indicates the battery charge. This is a steam plant and the engineer of the plant says the battery has materially decreased their cost of production and benefits them greatly in regulation and emergencies. The charge is given at a time when a large unit would be running at light load and the additional cost for charging the battery is very slight.

Figure 2 is a curve taken from an Eastern street railway system and shows the battery working under very severe conditions. This plant is a combined steam and water power system. It will be seen from the diagram that the battery takes two very pronounced peaks, one in the

*I have worked out the proposition and the above figure is approximately correct.—C. O. P.

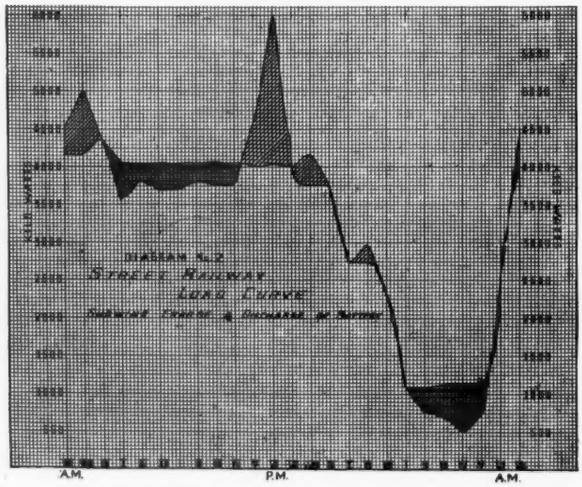
morning and another in the evening. It will also be seen that the battery is charged twice during the 24 hours, and the battery has been doing this double duty for nearly two years. The superintendent of this plant informed me



POOLE ON STORAGE BATTERIES.—FIGURE 1.

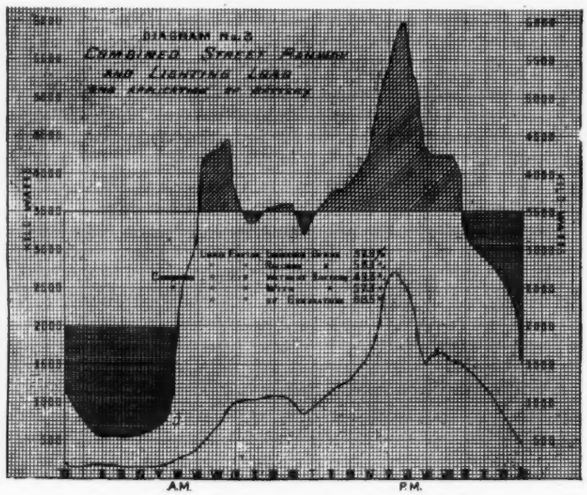
that had it not been for this battery, they would have been completely stalled many times during heavy snow storms.

Figure 3 is a load curve constructed by combining an Edison station load with a street railway load, and as this is the character of work with which transmission systems will have to deal, I have taken this curve for our example, having worked out the problem of carrying this load without storage batteries. Let us now see how it can be taken care of with the aid of batteries. I have stated that the economical width of a peak taken by a battery in connection with a steam plant was limited to about two hours. About three hours is the limit in our example for two reasons: first, on account of the excessive cost of a battery for carrying long-hour peaks; and second, because of the fact that the small-load hours are such that the battery could not be charged without going far beyond the normal charging rate. The maximum charging rate of the battery is about one-half the one-hour discharging



POOLE ON STORAGE BATTERIES.—FIGURE 2.

rate; if a battery is charged at too high a rate the losses are very much greater than at low rates owing to excessive gassing and heating. Taking all this into consideration, I have located the battery line at the 3500-kilowatt mark, thus cutting 2500 kilowatts off with the battery. If 2500 kilowatts are to be taken by the battery, it necessarily follows that but 3500 kilowatts in generators will be required; and in fact a like reduction can be made in all of the apparatus, and the installation in general, with the exception of the pole line and possibly the water storage system. The cost of the batteries and battery buildings, boosters, etc., of course must be added; without entering into the details, I will state that I have carefully worked out the proposition and made all proper deductions and additions. The amount added for batteries, etc., being in round figures $220,000 with everything considered, the installation complete will cost approximately $935,460. The figures in both cases I think are correct enough to draw a fair comparison. As the first in-



POOLE ON STORAGE BATTERIES.—FIGURE 3.

stallation would cost $1,115,000, it will be seen that a saving of $179,540 has been effected in first cost.

The fixed charges would be about as follows:

Interest on investment at 6 per cent.	$ 56,127
Deterioration and repairs at 7 per cent.	65,482
Operating expenses, same as before	40,000
Total fixed charge per annum	$161,609

Kilowatt-hours delivered per annum, $26,280,000.

Fixed charge cost per kilowatt-hour, $\frac{6.1}{100}$ths cent against $\frac{7.0}{100}$ths cent or a saving of 12.8 per cent., with an increased load factor of 7.7 per cent.

In my opinion this saving can more than be realized in actual practice, which is sufficient in itself to warrant the installation of the batteries, to say nothing of the many other advantages.

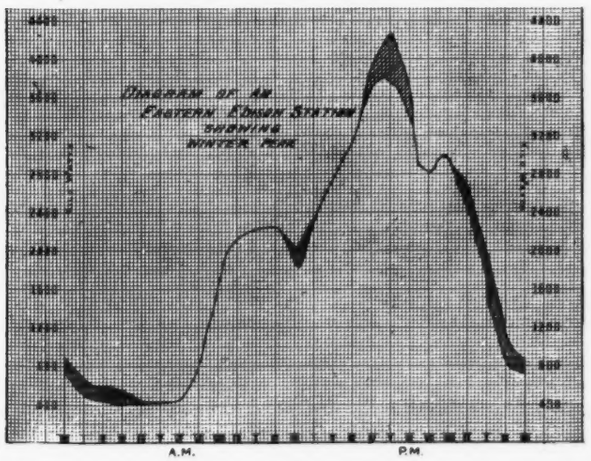
It might be said without exaggeration that a battery makes it possible to operate a transmission system with a single line, and as a matter of fact it is impracticable to give an uninterrupted service with a single line in any other way. With sufficient battery capacity it is possible to lay the line off for several hours at time of light loads, giving an opportunity for repairs or alterations, and in

this way the investment for a second line becomes unnecessary—an item I have not considered in my calculations.

In practice, the battery is kept floating on the system all the time, and it responds automatically and instantly to any fluctuations on the system, giving current to the distributing system at times of heavy loads and taking current from the line at times of light load. If required, the battery can be used to give alternating current to the line through motor generators or rotary transformers. The battery is especially useful in street railway work where the fluctuations are so rapid and unexpected that it is almost impossible to prepare for it.

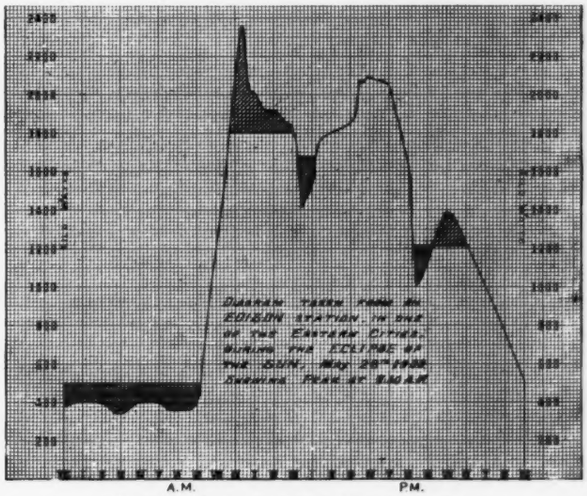
Not long since I was in the power.house of the Chicago Elevated Railway Company, and while watching the instruments on the switchboard the load would swing from almost nothing to 5000 horsepower in less than one minute. The engineer informed me that a short time ago the load came o ı so suddenly it wrecked one of their large engines. They are seriously considering the installation of a storage battery.

When batteries are used in parallel with compound wound generators or rotaries, it is necessary to use a differently wound booster in connection with the battery so as to allow the battery to take the fluctuations in load. If, however, the rotaries or generators are simply shunt wound, then the battery can be connected directly to the system and will take care of sudden fluctuations for short periods with a drop of about five per cent. at maximum rate of discharge. This is close enough for railway work; for lighting work the discharge is regulated by means of end cell switches, cutting in or out cells as required. When it is necessary to install a booster with a battery the apparatus and work should be so arranged that the booster be used as little as possible on account of the losses occasioned by its use. If the rotaries or generators are to be compound wound it will be well to provide their series field with a shunt adjustable from zero to maximum, and a short-circuiting switch, so that the machines can be operated as simple shunt machines. It is advisable to have at least one motor generating set, the generator to have sufficient range in its shunt winding to give about 28 per cent. increase over normal voltage when operating as a straight shunt machine. In this way the battery can be charged directly from the generator, thus avoiding the booster losses. This is leading into the subject of boosters and although the subject is a very interesting one, I fear we will not have time to discuss it here.



POOLE ON STORAGE BATTERIES.—FIGURE 4.

There is one more point that I wish to touch upon before closing, and that is the question of maintenance. The steam boiler and engine, as well as generators, etc., are in such common use that their cost for maintenance and repairs, etc., are so well established as to cause the prospective purchaser no uneasiness; but with a storage battery it is an entirely different proposition, and a prospective purchaser very wisely inquires what it is going to cost for maintenance.



POOLE ON STORAGE BATTERIES.—FIGURE 5.

In this connection, I wish to say, there are responsible companies in the field that will give a maintenance guarantee of from four per cent. to six per cent., depending upon the character of the work; that is to say, they will keep the battery within a reasonable percentage of its rated capacity for the above percentage per annum on its first cost. This figure is very much less than deterioration and repairs on running machinery.

As mentioned before, the high price of the battery has been its principal drawback, but I think we may confidently look forward to much lower prices in the near future; then the battery will be more generally used and its many advantages more fully realized.

MR. BABCOCK. I would like to ask Mr. Poole what is the loss in efficiency of the battery working under fair conditions as to capacity? I have always understood that, with a battery working under those conditions, there would be a decrease of about 15 to 25 per cent. per annum in its capacity, depending on the character of the load and the different working conditions.

MR. POOLE. As Mr. Babcock has intimated, everything depends upon the conditions under which the battery must operate. Of course, the real part of the battery is the lead oxide on the plates, and the deeper the oxide is used and the more frequently it is used, the more rapid the deterioration; if they are taking practically a full charge and discharge from it every day, the drop in capacity will be somewhere between 15 and 20 per cent. per annum. I know of batteries that have been on street railway

systems where it is simply used for regulating and taking care of fluctuations in the work. It has been in operation for about four years, and the capacity has only dropped somewhere about 20 or 25 per cent. It altogether depends upon the conditions and the uses to which the battery is put.

MR. SINCLAIR. Most of our members here are on the water power end of the controversy, and most of our developments are on that line. We have the opportunity, where the natural conditions are right, to put in a storage battery which does not wear out, which is very cheap and does its work, so far as supplying power is concerned, as effectually as a battery of the preceding nature, and that is by storing our water at the in-take. Wherever it is possible to store that water at the in-take, through small reservoirs sufficient to carry over the peak level, you would have the means of putting in a storage battery at an infinitely smaller expense than to purchase such a battery as Mr. Poole has intimated. But there is one thing that that storage reservoir of water will never take care of, and that is the line interruptions on a long line. The Edison company at Los Angeles has put in a storage battery, and is discussing the other proposition to put in water storage eventually. We put in a storage battery in Los Angeles simply and solely for the purpose of eliminating the question of line troubles liable to cause interruptions in the service, and we consider that in added business and added revenue it is a very paying proposition. However, we can see that as soon as we complete a small reservoir that we are at work on, we will have our power at the upper end saved for us in a very cheap manner.

MR. BABCOCK. I think there is one point Mr. Sinclair has not quite brought out in that: that while the water can be stored at the upper end of the pipe line, we will say, he is not saving anything in the cost of the pipe line or in the cost of the pole line, because both pipe line and pole line must be built with the maximum demand on the system. With the batteries properly designed and properly distributed, a condition can be maintained on the entire system where you will be running at your average load, and thereby save the original investment, which I think ought to be credited up to the storage battery, and it looks to me like a very material credit, too.

PROF. CORY. Adding to that something which, I think, is of even more importance. Take the case which Mr. Poole outlined; the equipment in generators will necessarily be about 3500 kilowatts; the equipment in storage batteries the remaining 2500 kilowatts in one particular instance. If we are going to store water it will be necessary to have in this case our 6000-kilowatt generator capacity, no matter how much we store the water. But in the other case, it is only necessary to have the 3500-kilowatt generator capacity, and the difference is considerably in favor of the storage battery method. Certainly the cost, however, of the storing of water in an ordinary transmission system would not be as great as the cost of a 2500-kilowatt storage battery; but we are saving in our installation of machines as well as in the line.

THE PRESIDENT. There is one point that it may be a little delicate to say anything about, but I believe it to be of interest to all the members of the Association. We are so far from the world tonight that we will have anyhow a week or ten days before the chloride people hear about it. If Mr. Poole would, in a few words, give his ideas about several different storage batteries, it might interest us to know if other storage batteries can be had, and if there is any hope of getting them cheaper than in the past. This year we are paying a very large amount of money to one firm, but during the year some other firms have been entering the field and are willing to take contracts for which they seem responsible. I would like very much, if you don't object, to have you say a few words about these different firms.

DR. VAN NORDEN. I would also like to add a query. I would like to know whether these responsible parties who sell storage batteries and give a guarantee for a certain percentage of cost during the year, whether that guarantee means a renewal or a protection of the Association, so that, say in 20 or 30 or 40 or 50 years from now, if the same arrangement lasts, the battery would retain the same efficiency. Is that what the guarantee means?

MR. POOLE. In that connection I might say that the different companies offer different inducements. Some companies will maintain your battery within 50 per cent. of its original capacity; that is to say, that when your plates have deteriorated to one-half the original capacity, they will renew the plates and restore it to its first capacity. Other companies will guarantee to maintain it within 90 per cent. of its original capacity; that is to say, that when it has lost 10 per cent. they will renew the plates sufficient to bring it up to its original contract rating. The cost would depend upon the conditions. It would be from four to six per cent. on the first cost of the installation. Our President has referred to a matter which I had the privilege of looking into some time ago, and there are responsible battery manufacturers that will supply new batteries with guarantees of maintenance and every other feature in connection with the battery, fully as good as the battery company referred to, and under terms somewhat more favorable than the old company. So that it looks very much as though within the next year or so we will be able to go to more than one market for our eggs, which, I think, will be a great relief to the community in general.

THE PRESIDENT. We must be fair and loyal to all the manufacturing concerns on whom we depend, in some measure, for the progress of the art, and we must give them due credit for the money they spend in going ahead; at the same time, to be loyal to manufacturing concerns, we must be loyal to all of them without exception, to those in the field and those entering it. The Philadelphia people for the last ten or fifteen years have absorbed almost everything in sight in the way of storage batteries. But for some reason they have been unable to reduce the cost of batteries to what it should be. Two or three new companies in the East are just now coming to the front, which should receive encouragement on general principles, from all of us. There is ample room in this branch of electricity for many manufacturers.

THE PRESIDENT. We have a short paper by Howard Hendrickson on Rate Meters; Mr. Doble will read it.

Mr. Robert McF. Doble then read the following paper on

RATE METERS.

BY HOWARD HENDRICKSON.

IT is universally conceded that to arrive at the proper rate to charge for electric current, two main features are to be considered; *viz.:* the fixed charges (interest and dividends on capital invested, depreciation and general expense account), and the variable charges, which may be called the generating and distributing cost.

The relative value of these two factors vary in every electric plant and with every consumer supplied.

To meet the commercial law that low rates are always conducive to largely increased consumption, and larger output insures reduced cost of production, it becomes imperative that a sliding scale be adopted in charging for current used to insure a universal profit on all customers.

Various devices have been suggested and used to determine what this rate should be in each individual case, notably maximum-demand meters. But these fail because a maximum-demand meter indicates the *highest* demand made on the station if but once in the whole period between readings; this will readily be seen is an injustice to the consumer if that maximum is used during the period and a charge based accordingly, as there is always one time during a period that a consumer would use more than ordinarily. For example, a contingency might arise dur-

ing the first part of the period that would render it necessary for him to turn on all the lights in his establishment possibly for not more than thirty minutes; this would force the maximum-demand meter up to its highest point or capacity, there to remain no matter how small a quantity of power is thereafter consumed during the balance of the period; this is a constant source of trouble and dispute between the station and consumer and discourages the customer in freely using electricity.

The record of the demand made by the consumer for one isolated time is no benefit to the station, as isolated individual maximum demands made by several customers would be made at different times and on different days and the station would not be called upon to supply the sum of these demands at one time; but if an individual consumer made repeated demands upon the station knowledge of this fact would be desirable to fix an equitable rate to offset the increased installation required to meet that demand.

On the other hand, a thorough knowledge of the several rates of consumption made by consumers would make it possible to fix low rates and thereby encourage the use of current over more hours and thus more evenly load the plant and thereby enure to the benefit of the station.

Vibrators are disadvantageous inasmuch as they are not automatic, making it necessary to guess at the amount of current to be used to set them in the first instance, which varies for every month of the year, or devolving on the consumer the necessity of making subsequent adjustments, which, if made in the middle or latter end of the month, causes him to feel overcharged for the first part.

A perfect rate meter must not only be automatic and thereby register the lowest rate demanded, but must not register the maximum rate until that demand has been made a sufficient number of times to make it necessary to set apart a definite portion of the installation to meet that demand. Such a rate meter, in an installation driven by water power, or in other words where the fixed charges greatly predominate, would meet all wants in a most satisfactory manner, no recording watt-hour meter being necessary in such a case, as by it, proper charges, based on the installation operated to supply each individual customer, could be made.

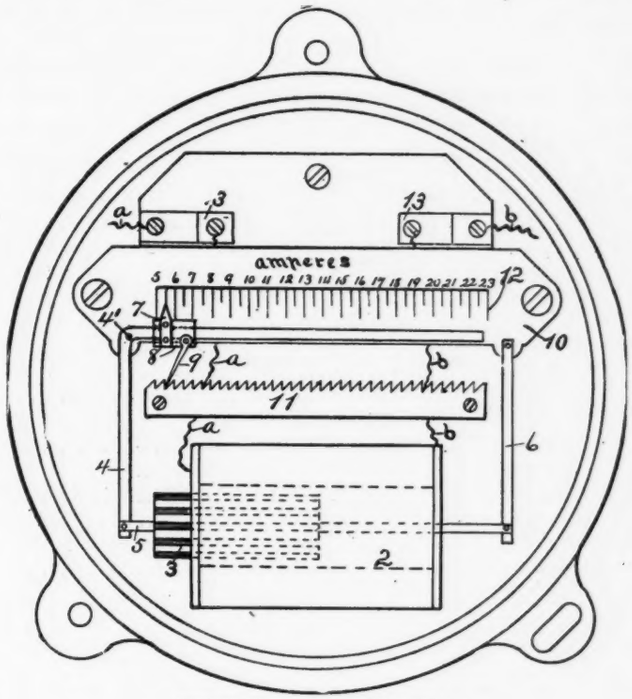
In plants where the generating and distributing costs are high, a recording watt-hour meter is a necessary adjunct to the rate meter; together they leave nothing to be desired, as by their use the long-hour customer with light demand and the short-hour customer with heavy demand can be singled out and equitable rates, based on costs to the station, made.

Another advantage in the use of a rate meter is keeping down the peak load, which determines the capacity of the plant, thus increasing the efficiency by making it possible to use the peak load margin in supplying more customers and giving greater satisfaction by supplying current at a lower rate per kilowatt-hour.

In ordinary flat-rate contracts based on lamps installed, the consumer limits the number to the smallest amount and to get the full value burns them as long as possible; the station manager must combat this tendency by a high rate; the result is small business and high peak loads.

In contradistinction where rates are based on average demand, houses are more liberally wired and where the convenience is at hand the tendency is to use it, and with the better rate a better satisfied and more profitable customer accrues to the station.

It is believed that a device which will meet all foregoing requirements which are essential to a perfect rate-indicator has now been devised and is described in U. S. Letters Patent No. 640466, issued to Jesse Harris, January 2, 1900.



HENDRICKSON ON RATE METERS.

The accompanying sketch will give an idea of its construction. It consists of a solenoid within the open interior of which is drawn a laminated core of iron by the current traversing the coil; the pull on the core is opposed by a weight carrying a pointer in front of a scale arranged by means of a pawl and rack to travel out on an arm. It operates as follows:

When the pull of the solenoid is sufficient to overcome the weight the arm will raise and the pawl attached to the weight will advance one notch in the rack; in this position the meter will be in position upon decrease or shutting off of current to advance one point and register; this operation is repeated at each subsequent time that the current reaches a magnitude greater than last registered. After reading, the meter is reset by sliding the weight to its original position.

The meter here described is a simple mechanical device not liable to get out of order and for accuracy can be relied upon.

MR. POOLE. The instrument just described is very similar in its action, or the result of its action, to the Ritz demand meter, which is an apparatus that is quite cheap, and I think will fill every field that the instrument just described would. But it seems

to me that that maximum-demand meter is lacking in one thing: that is to tell at what hour this maximum load comes. That is the very point the central station people want to know, and a very much better arrangement would be a two-rate mete.. There are two recording dials, and those dials can be set to shift over at certain hours, and those hours can be overpeaked hours, and the two rates charged for the two different currents used at different times.

PROF. CORY. Just one word in connection with what Mr. Poole has said. I think the point that he has brought out is a very important one. We not only want to know that the peak does occur, but we want to know when it occurs. I have in mind a little device to which I have been giving some attention. It is not perfect, by any means. I wish I could say it was perfect. But the attempt was this: It is very well understood that we can get the indicated watts very nicely from an ordinary integrating wattmeter by taking the number of revolutions per minute. I have had a little experience in testing meters recently, which leads me to believe that with certain types of meters the number of revolutions increases simultaneously with an increased load. If we but had some device with a mechanism which would record the number of revolutions per minute of this dial for each minute of a period of 24 hours, we would have absolutely everything that is wanted. If, for instance, a meter revolves 50 revolutions on full load per minute, and we go to our recording device and find that this meter has, between the hours of 5 and 9, recorded 50 revolutions per minute, we know that the watts used equals the maximum capacity of the meter. On the other hand, if between the hours of 9 and 12 it has been going 20 revolutions a minute, we know that it has been carrying two-fifths, and so on. I did succeed in making a single instrument which could be put on a circuit in order to determine the load factor. That is exactly what was intended—to put it on a commercial recording wattmeter and determine by this device, for a given load, the load factor.

The problem is, of course, an old one, of determining the number of revolutions per minute of any given device and actually recording the number of revolutions. The chronograph is the instrument we use in a laboratory. Its use is impossible commercially. In the case of meters it is a little worse than ordinary conditions. We must record the number of revolutions of a very light disc which has a very small power driving it; it seems to me that is the kind of thing we want to get. If we were to go to that meter at the end of the month, not only would we find the actual power recorded on the dial, but we could go to the recording device and find the actual power taken at any interval we choose during the entire month.

MR. SINCLAIR. In that line, I will say that at the request of our Redlands company last year, the General Electric Company and another concern which manufactures recording instruments, joined together and made for our company a recording wattmeter registering on the usual form of charts, which, for a polyphase system, would show the load at any moment of the day. However, it came to us very late, and the particular use to which we had intended to put it had changed in the meantime, hence we have not used it; but I believe it is to go up on an installation of about 75 horsepower within a day or two if it is not already on. I think Mr. Lighthipe is somewhat familiar with the details of it.

MR. LIGHTHIPE. I don't know the details of that instrument exactly.

MR. SINCLAIR. It did not come under my particular supervision. It was turned over to our engineer and the General Electric Company together.

MR. HUTTON. I saw a description of an instrument something over a year ago that does the very thing of which Professor Cory speaks. It is a clockwork device and is attached to an ordinary recording wattmeter, revolutions being recorded by making a little dot on a slip of paper. If the meter is revolving fast, the dots are close together, and if slow, they are far apart, from which one can tell what the load is. One of the things we have to contend with is the small residence lighting customers. In the majority of cases, where we have water power transmissions, we try to get as much business as we can. In order to do that we make the rates as low as possible in order to get as many customers as possible, and then the question of a high-priced meter becomes a very serious matter. It seems that if we could get some small instrument such as Professor Cory speaks of, that would be cheap enough, it would be a very good thing, particularly for residence business. For commercial business that we have to determine with meters, we can well afford to buy an expensive instrument that will give us good results, but the one thing we have to look for now is something cheap for residence work. I think the meters for commercial business, though, are in shape now so that a person can get what is required.

PROF. CORY. If I might answer Mr. Hutton I will say that I am a little afraid that this contrivance I have mentioned would never do for residence lighting. I think, however, it could be used in this way very successfully with one exception; you can use it to determine your customer's load factor and then install the cheapest kind of a meter you can get which is accurate. At the end of the month, you will record a certain quantity. It will give you the average watts for that month. You have previously determined the load factor. Your rate that you intend to charge for residence light will depend upon the load factor if you get the return that you ought to get for what the customer is costing you.

The exception is this: I live, we will say, on a street, and have a neighbor next door, and we both take electric light. We each use the same amount of electrical energy. The load factor that I have is the worst possible; the peak comes at the wrong time. My neighbor, however, has a good load factor, perhaps. Neither of us knows anything about this unfortunate peak load. At the end of the month I find that my consumption is exactly equal to my neighbor's in average integrated watts. You come to me and you say, "Mr. Cory, your rate is," we will say, "eight cents." I go to see my neighbor, and he tells me he has a rate of five cents, and the result is that I come down to your office pretty hot over the proposition. I merely mention that because it is exactly what occurs, and if I only understood that my power was perhaps eight-fifths as expensive to you as my neighbor's, I would not object to the higher rate. That is the exception. If we could get a meter which would run faster during the time of the peak load, we could even eliminate this purely personal trouble. Commercially, you know what these things amount to. A man gets a certain amount of electrical energy and thinks he ought to pay only for that amount.

MR. HUTTON. You could do it in one way; take the ordinary meter and take the drag disc off. As the load increased the meter would run a great deal faster in proportion to the load.

PROF. CORY. You only want that in certain hours.

MR. SINCLAIR. I am afraid he would become suspicious if you came around frequently to take the drag off and put it on again.

DR. VAN NORDEN. I doubt very much whether it is necessary to have meters at all. We don't find it so in Sacramento. We have a very satisfactory system there. It is satisfactory to us because we get a large return for our power—$40 a year for each horsepower that is disposed of to customers, and the power is brought back to us to be used on a railroad. For that we get another price. We have a system of minimum charge; we won't connect with any house for less than $2 a month; hitherto we have allowed them eleven lights at that, but at present we allow them seven lights for the $2. It brings us in a good income for our power; a very good income. It is highly satisfactory to the people today; they have a few lights and they can burn as much as they please. They come to enjoy illumination and they do make large use of it, and we get a fair return for the power that they actually take. Some abuse the privilege, others don't live up to the level of their privilege, and you can average the matter. Take it as a whole, we get certainly $40 a year per horsepower; that I think is a good return. I can't see any use for expensive meters and also expensive service required to take care of them. There is an enormous amount of office detail which you avoid. Our system is very simple and economical, we get a good return

for our current, and we have great satisfaction among our customers. They enjoy their light; they are not thinking all the time of the bill at the end of the month; they know exactly what they are going to pay. A poor family that has seven lights illuminates a small cottage beautifully, has just as much light as it pleases, and pays only $2 a month. That seems to be perfectly satisfactory to them, and, so far as I am concerned, it is perfectly satisfactory to us. There are certain cases where there are a great many lights in a large palatial mansion—perhaps 75 or 100. In those cases it is very hard to try a flat rate, because you can't tell how much current will be used, and the flat rate would seem extremely pleasant to him if he paid on what he probably would use, and if we gave him any ordinary flat rate, he might use an amount of power that would be worth three or four times what we charged him. In that case there should be a meter, unless perhaps, we are certain of our customer and know what his habits are. In most cases we don't know that. While I believe that for a certain portion of our business it is wise for us to have meters, for nine out of ten of our residential customers, and nine out of ten of our commercial customers, there should be, not a meter, but a flat rate. That gives us a good return, and it creates a spirit of satisfaction among the customers.

MR. EASTWOOD. I want to state our experience in Fresno. Nearly all of our customers are on the flat rate where they are using lights in residences, except, as Dr. Van Norden says, where they are large owners, and there we put in recording meters. The great difficulty about the universal application of meters to residence lighting is the fact that they are very small consumers, and that the return would not pay interest on the investment. We thought the best way to do was to make a graduated scale of prices, to give them three lights for a certain amount of money, and four lights far a certain amount, and so on, and let them take it at a flat rate. There is only one device that I know of that could be used, and that is the Lacy limited meter.* It is practically connected with a flat rate. You charge a flat rate for the number of lights that the meter will allow to burn, and they can install as many lights as they please and burn them in whatever part of the house they please. It is a convenient arrangement for the customer and a very nice arrangement for the lighting station, because you know exactly how much current you have to supply to each particular customer, and you get your money for it. Our experience is that for all large consumers we are putting in meters very rapidly all over the system, and for residence lighting the flat rate seems to be most satisfactory for all concerned.

MR. HUTTON. It seems to me there is a distinction that is drawn by Dr. Van Norden and the other gentleman, between the two classes of customers; that is, the one that has got a large number of lights in his house and the other one having a small number. In one case you have a big bugaboo, and in the other case a whole lot of small bugaboos. I don't see why the smaller ones should not be treated the same way that the larger ones are. You say it is all right to put in a meter on a large customer because he has more lights in his house. I can't see where the difference is, where the house is small and the number of lights is small.

MR. EASTWOOD. The proposition is simply this: that from the station manager's standpoint, it would not pay to put meters in for small consumers. It is better to take the flat rate and have done with it.

MR. HUTTON. In the case of the large customer, there is probably a little more income, and you can afford to buy the expensive meter. In the case of the small customer, if you can get something cheaper for that, it answers the same purpose.

MR. SINCLAIR. I think that there is a point that you are losing sight of here. I think Dr. Van Norden's experience may be based upon the fact that he has always operated under water power and perhaps has had a surplus of water, and he has never felt the necessity for economizing. We started in assuming that we could make flat rates. We did make flat rates very generally, everywhere, both for business lighting and residence lighting. When dry times came on, and we reached the limit of our water power, and then had to build a thousand-horsepower steam plant, we found that the only way to save ourselves at all was to put meters in for large and small customers alike. We protect ourselves on the meter investment by charging a minimum rate, as I guess most companies do, for the installation of meters. We had customers on our system with five lights installed who would actually consume far more power than other parties with 25 lights installed. There was only one fair way, in our experience, and that was to meter all and make quantitative discounts for the monthly bills, giving them a graduated discount according to the quantity used.

MR. CLARK. There is a system used in a number of stations that I have seen where they make a minimum rate of $2 a month where they have a meter, and they make a practice of installing a meter in every place. What I mean by that is, that if the light consumed by the meter amounts to $2 a month, they make no charge for the rent of the meter. If it is less than that, they charge 50 cents a month rent for the meter.

(The balance of the papers read and the discussions thereon will appear in the August number of the JOURNAL.—THE EDITOR.)

*Described in THE JOURNAL OF ELECTRICITY, Vol. IX, page 44, February, 1900.—THE EDITOR.

THE SOCIAL FEATURES OF THE CONVENTION.

Mount Tamalpais has, through the unqualified success which attended the Fourth Annual Convention of the Pacific Coast Electric Transmission Association, earned the enviable distinction of being the most perfect location within the confines of the Golden Gate regions for the holding of association meetings. Fast and frequent train service between San Francisco and Mill Valley over the line of the San Francisco and North Pacific Railroad, the exhilarating climb up the mountain sides over the Scenic Railway, the perfect service and almost luxurious furnishings of the Tavern of Tamalpais, the comfort of the pavilion as a convention hall, the unequaled grandeur of the view and the gorgeous sunset and sunrise, all tend to blend pleasure with the work in hand so insensibly that one's best thoughts and efforts must preponderate. It is, perhaps, to this unconscious blending of business and pleasure that the extreme value of the discussions which took place is largely due.

One of the most graceful features of the Convention was the presentation by the President, Pce. A. Poniatowski, of the exquisite button to each member in attendance. This button, which was adopted as the official badge of the Association, and a likeness of which is reproduced in exact size on the initial page of this issue of the JOURNAL, is of solid gold, with the words "Pacific Coast Electric Transmission Association" inlaid in gold on a blue enameled background. The pole, cross-arms, insulators and wires embossed in the medallion thereon, fittingly typify the Association as being of the home of the longest distance, highest potential electrical power transmission systems of the world.

On other pages of this and ensuing editions of the JOURNAL appear the papers presented to the Association, together with the official report of the discussions held upon them. In brief, the programme followed during the Convention is as follows:

TUESDAY, JUNE 19, 1900.

9:30 a. m. Left San Francisco by Sausalito Ferry, foot of Market street.

11:30 a. m. Arrived at Tavern of Tamalpais.

12 m. Luncheon.

1:30 p. m. Convention called to order in the Pavilion, and proceeded to the reading of papers as follows:

"Regulation in Long-Distance Transmissions," by Frederic A. C. Perrine, D. Sc.

"Arc Lighting for Interior and Street Service in Connection with Power Transmissions," by H. W. Hillman.

"Transformers for Transmission Service," by H. C. Wirt.

"The Choice of Alternating-Current Motors," by R. S. Masson.

6:30 p. m. Dinner in banquet hall of the Tavern of Tamalpais.

8:30 p. m. Convention reconvened in the Pavilion, and proceeded as follows:

"The Application of Storage Batteries to Transmission Systems," by C. O. Poole.

"The Factor Determining the Water Supply of California," by Marsden Manson, C. E., Ph. D.

A Stereopticon Exhibition of Representative Electrical Transmissions of America, by Geo P. Low.

WEDNESDAY, JUNE 20, 1900.

9:30 a. m. Convention meets in the Pavilion, and concludes its session with the following papers:

"Transmission System Regulation," by Prof. C. L. Cory.

"Atmospheric Electricity," by Alexander G. McAdie.

"Rate Indicators," by Howard Hendrickson.

At 4:30 o'clock on the afternoon of the first day, the full members of the Association went into executive session during which the following were elected as officers of the Association for 1900-01:

President, Pce. A. Poniatowski;

Vice-President, Dr. Chas. Van Norden;

Secretary, Geo. P. Low;

Treasurer, Wm. Angus;

Members Executive Committee, C. P. Gilbert and E. J. DeSabla.

The photograph from which the engraving of the group of those who attended the Convention was made, was taken by L. D. Hitzeroth, through whose courtesy each member present has received a copy. Unfortunately, Mr. Hitzeroth's features, as were those of Mr. Wishon, were partially eclipsed during the transit of the camera's shutter. Further references to the photograph may be concisely stated: Mr. Theberath does *not* wear a monocle, although he appears to do so; Robert McF. Doble, though uncommonly tall, was *not* standing on the floor; though No. 22 is by nature the jolliest of the jolly, the photograph given is *not* that of comedian L. R. Stockwell; and, finally, the profile of J. S. Eastwood as reflected in the window, is *not* true to nature — it is, in fact, but a paneful distortion.

The convention finished its labors on Wednesday forenoon and the majority of members returned to San Francisto in the afternoon.

The following are the names of those who attended the Convention, together with the name of the concern or interest represented by each:

Angus, William, Secretary Standard Electric Company of California, San Francisco;

Babcock, A. H., Assistant Electrical Engineer, Standard Electric Company of California, San Francisco;

Barrett, S. F., Engineer State Insane Asylum, Patton, California;

Briggs, W. W., representing Westinghouse Electric and Manufacturing Company, San Francisco;

Butler, A. J., representing the Byron Jackson Machine Works, San Francisco;

Clark, True S., Engineer Wagner Electric Manufacturing Company, San Francisco;

Cole, John R., manufacturers' agent, San Francisco;

Cory, Prof. C. L., of the Engineering Offices, 319 Pine street, San Francisco;

Cushing, S. B., President Mill Valley and Mount Tamalpais Scenic Railway, San Rafael;

Doble, Robert McF., General Superintendent Snoqualmie Falls Power Company, Seattle, Wash.;

Doble, Wm. A., President Abner Doble Company, San Francisco;

Eastwood, J. S., Manager San Joaquin Electric Company, Fresno;

THOSE WHO *TRIED* TO "LOOK PLEASANT" AT THE TAMALPAIS CONVENTION.

1. Wm. Angus, Treasurer
2. Prof. C. L. Cory
3. Geo. P. Low, Secretary
4. Dr. C. Van Norden, Vice-Pres.
5. Pce. A. Poniatowski, President
6. C. P. Gilbert
7. A. H. Babcock
8. A. G. Wishon
9. H. H. Sinclair
10. W. H. Hammond
11. T. E. Theberath
12. J. S. Eastwood
13. W. A. Handcock
14. F. M. Ray
15. C. Wm. Hutton
16. R. H. Stirling
17. T. H. Van Frank
18. J. A. Lighthipe
19. Lewis A. Hicks, C. E.
20. True S. Clark
21. A. J. Butler
22. W. W. Briggs
23. Marsdon Manson, Ph.D., C.E.
24. W. Frank Pierce
25. William A. Doble
26. L. D. Hitzeroth
27. C. O. Poole
28. Robert McF. Doble

Gilbert, C. P., General Manager Standard Electric Company of California, San Francisco;
Hammond, W. H., President Mount Whitney Power Company, Visalia;
Handcock, W. A., late of the Canadian Bell Telephone Company, Sherbrooke, Que.
Henry, Jr., Geo. J., Engineer Pelton Water Wheel Company, San Francisco;
Hicks, Lewis A., Kern County Land Company, Bakersfield;
Hitzeroth, L. D., Superintendent Electrical Department of San Francisco Gas and Electric Company, San Francisco;
Holland, J. L., Official Stenographer, Mills Bldg., San Francisco;
Hutton, C. Wm., Electrical Engineer Sacramento Electric, Gas and Railway Company, Sacramento;
Lee, F. V. T., Manager Jno. Martin & Co.'s electrical agencies, San Francisco;
Lighthipe, J. A., Engineer General Electric Company, San Francisco;
Low, Geo. P., Editor and Proprietor THE JOURNAL OF ELECTRICITY, POWER AND GAS, San Francisco;
Manson, Marsden, C. E., Ph. D., San Francisco;
McAdie, Alexander G., Section Director U. S. Weather Bureau, San Francisco;
Pierce, W. Frank, President Blue Lakes Water Company, San Francisco;
Poniatowski, Pce. A., President Standard Electric Company of California, San Francisco;
Poole, C. O., Superintendent Standard Electric Company of California, San Francisco;
Ray, F. M., Sales Agent General Electric Company, San Francisco;
Scribner, H. D., Sales Agent Westinghouse Electric and Manufacturing Company, San Francisco;
Sinclair, H. H., President Redlands Electric Light and Power Company, Redlands;
Stirling, R. H., Superintendent the Bay Counties Power Company, San Francisco;
Sutcliffe, E. W., Engineer the Butte County Electric Power Company, Chico;
Theberath, T. E., Engineer Yuba Power Company, San Francisco;
Van Frank, T. H., Manager Brooks-Follis Electric Corporation, San Francisco;
Van Norden, Dr. Charles, President Central California Electric Company, Sacramento;
Wallis, Col. Geo. H., Superintendent Pacific Works of American Steel and Wire Company, San Francisco;
Wishon, A. G., Vice-President Mount Whitney Power Company, Visalia.

The ladies who attended the Convention were:

Mrs. A. H. Babcock, Mrs. W. W. Briggs, Mrs. Thomas Cory, Mrs. W. A. Doble, Mrs. George J. Henry Jr., Mrs. L. D. Hitzeroth, Mrs. J. A. Lighthipe, Mrs. Geo. P. Low, Mrs. Alexander G. McAdie, Mrs. Marsden Manson, Mrs. H. D. Scribner, Mrs. E. W. Sutcliffe, Mrs. T. H. Van Frank, Mrs. S. H. Weidenthal.

VAN DER NAILLEN GRADUATES FOR 1900.

Following is a list of graduates for 1900 in the electrical department of the A. Van der Naillen School of Engineering:

California—Guy A. Dunn, Oakland; Henry K. Zeimer, Oakland; H. C. Hasselbach, Chasdon; E. J. Bowen, San Francisco; Ed. W. Milenz, Napa; J. F. Endert, Crescent City; Joseph Levansaler, Napa; R. E. Morgan, Miramonte; T. P. Doughty, Rodeo; R. E. Cranley, Oroville; J. Hayne, Fort Mason; B. Dougall, Marysville; H. M. Hoare, San Francisco; C. E. Howard, McCloud River; Jas. M. Boyd, Sissons; P. W. Smith, San Francisco; H. Jesser, Biggs; R. Rassermussen, Ferndale; D. Martin, Poplar; Percy M. Levi, Oakland; M. Loken, San Francisco; H. Adair, Oakland; Will Eipper, Gilroy; Ed. Blake, Park City, Utah; C. E. Lowrie, Wheatland, N. D.; Ed. Mercer, Seattle, Wash.; A. R. Powers, Virginia City, Nev.; James Dorgan and F. Bottcher, U. S. A.

"The JOURNAL demonstrates the high stage that electrical engineering and education have reached on the Pacific Coast," says the *Electrical Engineer* (New York.)

Hydraulics

SOME DATA ON PUMPING BY ELECTRICITY.*

BY LEWIS A. HICKS, C. E.

THE company for which I am acting as engineer—the Kern County Land Company—went into the pumping business three years ago and as they contemplated an investment of some magnitude it was decided that some experiments should be made to determine which of the many types of pumping plants offered by the various manufacturers were best adapted to our needs. This investigation was carried out under my supervision and included careful tests of many of the principal types of pumps available for irrigation purposes. Our testing equipment was as complete as money could provide, including $1200 worth of electrical instruments, and the results were checked and rechecked until we were entirely satisfied as to the correctness of our conclusions. The object of these tests was in all cases to establish the amount of power required to drive the pump mechanism when delivering water against a list approximating actual conditions, and the results were expressed as a ratio between the power consumed and the useful effect produced, thus establishing the efficiency of the apparatus and enabling a comparative statement of the merits of all the pumps tested. The efficiencies observed ranged from 20 per cent. to 68 per cent. and disclosed the wide range in real value of the pumps offered for sale.

This will appeal to you more forcibly if you happen to buy the pump which requires more than three times as much fuel to do the same work as your neighbor who was fortunate enough to purchase the better machine without, perhaps, expending any more money than you did.

As conditions change, each style of pumping apparatus finds its peculiar field to which it is better adapted than any other, but as the result of our experimental work I may make the broad statement that the centrifugal pump properly modified and adapted to its work is the most economical form of pump under the conditions prevailing in the southern part of the San Joaquin Valley, including your own county, and that where electric power can be obtained at the very reasonable prices which are available in this vicinity there is nothing which can excel these plants in cheapness of first cost, operation, maintenance and durability. We developed a special type of centrifugal adapted to low lift and high speed—characteristics which make it possible to directly connect the pumps to standard high speed induction motors. During the year past we have operated 25 pumping plants, each delivering from 1400 to 2000 gallons per minute, and it may be said in a very literal sense that the investment has been fully justified by the prevailing drouth conditions. The average cost of our plants has been about $3500.

Each station consists of four wells in a line sunk to a depth of 80 to 130 feet through strata of alluvial loam clay and water-bearing sand. The wells are cased with galvanized iron casing 13 inches in diameter, No. 16 gage, perforated with vertical slits opened about a sixteenth of an inch. Our practice has been to land the casing in clay and perforate all the sand passed below a depth of 30 feet. The shoe on the starter is somewhat larger than the casing, and by means of a small supplementary sand pipe sunk to the first water sand encountered, the large casing is enclosed in a layer of coarse sand which, while effectually excluding the flow of fine sand, offers little obstruction to the water entering the casing. Surface water is encountered at a depth of 10 to 15 feet and as a rule a flow of three to four cubic feet per second is secured when the thickness of the water sand is from 20 to 30 feet. Much depends on the care and skill exercised in sinking the wells, securing a proper landing and adapting the perforations to the sand encountered. The wells are six feet apart on centers, and we find that the flow from four wells is a little more than double the quantity supplied by one well.

The sills of the pit on which the pump is set are placed at the

*Remarks delivered by the author before the Farmers' Institute at Tulare.

surface water level and the water is exhausted in the wells to a depth of 22 to 28 feet, making the total lift from 35 to 40 feet. The pit is excavated to water and lined with redwood one inch thick.

The pump is set in the center with two wells on either side and is of the ordinary centrifugal pit type with a specially designed runner adapted to permit of direct connection to a high speed, vertical shaft motor, without sacrifice of efficiency.

The pump sets in a steel frame which extends to the surface of the ground and carries the weight of the motor. If you are interested in the technical side of this matter you will find a complete description of the experiments which resulted in the development of this type of pumping plant in the July, 1899, number of THE JOURNAL OF ELECTRICITY, POWER AND GAS, published in San Francisco, but it will be sufficient to say to you now that we have found them entirely satisfactory in practice. The pumps are scattered over a wide area of lands belonging to the company and are operated by three attendants and one inspector.

The attendants are paid $40 per month and are required to visit each station under their charge from once to twice a day. The stations are so far apart that the men have to ride from 25 to 30 miles a day to perform their duties and one man operates as many as ten plants. The inspector is a skilled mechanic, who, as far as possible, anticipates any deterioration, and when accidents do occur is prepared to make repair with least delay possible. The result of this system and the general excellence of the mechanical installation is shown by the fact that during the past year there have been months when the actual operating time of all our pumps was over 98 per cent. of the possible time. The pumps run night and day, Sundays included, except when current is shut off the lines to permit electrical repairs, and beneficial use is made of the water throughout the year. Continuity of service and large volume with constant demand for the water are the requisites for successful and economical pump irrigation. We have met these conditions by the use of electric power, by grouping several pump stations together within a quarter of a mile of each other and by utilizing the water pumped on our own forage crops when no other demands exist for its use elsewhere. You all appreciate from practical experience that half your usual irrigation head means difficulty in irrigating one quarter the acreage you could handle in a day with a full supply—and you will therefore see the advantage of combining the flow from several pumping stations.

Our experience has demonstrated in a practical way that pumping to reasonable heights can be made a commercial success. I have been astonished today at the statements made by several speakers as to the cost of pump irrigation ranging from $5 to $12 per acre, because in Kern county, where the land requires irrigation to the extent of two acre feet annually, we are selling pump water to the farmers at the rate of 75 cents per acre foot and the cost per acre per annum is under, rather than over, $1.50.

While this figure does not mean large profits, it may be said safely that it covers power, attendance, interest and depreciation and does not involve any loss to the operating company. Individual installations will not attain results as favorable as those mentioned because the necessary experience and organization are not available on a small scale, but where electric power can be had as cheaply as you obtain it here and neighbors combine to construct pumping plants for joint use in rotation, the cost per acre should not exceed $2.50 per annum.

With the advent of the petroleum development in California will come the use of crude oil under steam boilers and the lighter distillate in oil-burning engines in conjuction with deep well lift pumps, air lifts and propellers, all of which are adapted to certain conditions and localities.

Pumping not only offers the best possible insurance against drouth conditions, but will make available for beneficial use of many thousands of acres which could never be reached by gravity systems, and ranks in importance with the conservation of flood waters by means of storage dams.

The pumping system installed by our company during the past two years is equivalent to a mountain storage of 100,000 acre feet, and when you ascertain from the reports of F. H. Newell, the government official in charge of the irrigation investigation, that there are very few reservoir sites of equal magnitude in this State and that years have been spent in attempting to secure appropriations to construct the first of these required dams, you will begin to grasp the importance of the subject and realize that private capital is rapidly making irrigation history in this direction.

Every citizen of our country, regardless of residence, should be interested in extending the area of our cultivated lands to relieve the congestion of population in our Eastern states. Every additional acre of land irrigated in the West tends to reduce the pressure of economic conditions in the East, and as this development is in the interest of all it would be only reasonable to expect that the Federal government should assist by giving our farmers the benefit of an expert examination and report on the relative merits of all typical devices offered for sale and a clear, practical statement of the conditions suitable for each kind of pump.

THE MINERS INCH AND ITS EQUIVALENTS.*

ONE miners inch corresponds to 1.5 cubic feet of water per minute. This is the legal allowance in Montana, and is a fair average of the measurements actually used in California and other States where no exact value has been prescribed, and where the amounts sold by different water companies vary.

ONE MINERS INCH IS EQUIVALENT TO:

	U. S. Gallons	Imperial Gallons	Cubic Feet Water	Lbs. Water	Tons Water	Kilogram's
Per second	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{10}$	1.56	0.0008	0.71
Per minute	11.2	9.3	1.5	93.5	0.047	42.5
Per hour	675	562	90	5620	2.8	2550
Per day of 24 hrs.	16,200	13,488	2,160	134,880	67.5	61,180

HORSEPOWER DEVELOPED FOR EACH 100 FEET OF FALL:

WATER UNIT.	Theoretical H. P. at 100 per cent. efficiency	Available H. P. at 90 per cent. efficiency	Available H. P. at 80 per cent. efficiency
By 1 miners inch	0.3	0.26	0.24
By 1 cubic foot per minute	0.19	0.17	0.15
By 1 pound per minute	0.00303	0.0027	1.0024
By 1 U. S. ton per minute	6.07	5.5	4.85
By 1 U. S. gallon per minute	0.025	0.021	0.02
By 1 Imperial gallon per minute	0.303	0.027	0.024
By 1 kilogramme per minute	0.0067	0.006	0.0053

To obtain 1 horsepower at 100 feet pressure requires 3.5 to 4 miners inches; or, per minute, 6 cubic feet, 350 to 400 pounds, 40 to 50 U. S. gallons, or 30 to 40 Imperial gallons of water.

CONVERSION TABLE FOR WATER:

U. S. Gals.		Imp. Gals.		Cubic Feet.		Pounds.		Tons.		Kilogrammes.
1.	=	0.833	=	0.133	=	8.33	=	.....	=	3.77
1.2	=	1.	=	0.16	=	10.	=	.005	=	4.54
7.5	=	6.25	=	1.	=	62.5	=	$\frac{1}{32}$	=	28.4
0.12	=	0.1	=	0.016	=	1.	=	.0005	=	0.454
240.	=	200.	=	32.	=	2000.	=	1.	=	907.
0.274	=	0.22	=	0.035	=	2.2046	=	.0011	=	1.

In the above table the U. S. gallon is taken as 8.333 pounds water, which is very approximately correct; on this basis 5 Imperial gallons = 6 U. S. gallons.

One U. S. gallon per minute = 6 tons of water per day. One U. S. gallon per hour = $\frac{1}{10}$ ton per day.

*From the *Mining and Scientific Press.*

Gas

EIGHTH ANNUAL GAS ASSOCIATION MEETING.

MIDSUMMER is pre-eminently the season of association meetings on the Pacific Coast, especially in the lighting and power industries, for the Pacific Coast Electric Transmission Association holds its annual convention in the third week in June, while the Pacific Coast Gas Association convenes in the second week of July. As the forms for this issue of the JOURNAL go to press, the last named organization is concluding its eighth annual meeting, and, as has heretofore been pointed out in these columns to have been the case with the convention of its sister association of electrical proclivities, the gathering of the Gas Association was highly profitable and enjoyable—in fact it was by far the most successful yet held. Considered from a broad engineering standpoint, the most interesting matters brought before the Gas Association were suggested in the papers by J. B. Crockett, on "Larger Types of Gas Engines," and by A. C. Humphreys, on "The Investigation of Gas Processes." Mr. Crockett verified the prediction made by a recent editorial in the JOURNAL to the effect that San Francisco is soon to be the field of a triangular battle between the three great rivals for supremacy in the lighting and power industry, namely: steam-driven electric stations, as exemplified by the high-grade plant of the Independent Electric Light and Power Company; electric power transmission, as exemplified in the extreme high-voltage, long-distance system of the Standard Electric Company of California; and gas-driven electric stations, as exemplified in the new installation which Mr. Crockett states that the San Francisco Gas and Electric Company is about to make, wherein a 300-horsepower quadruple-cylinder gas engine, utilizing producer gas, and which is being built by the Union Gas Engine Company of San Francisco, is to drive a direct-current unit to be run on the Edison three-wire system of the company named. Mr. Humphreys, on the other hand, denounced the now notorious "Hall process" of gas making in most unmeasured terms and with somewhat extended reference to the direful experiences of the Equitable Gas Light Companies of San Francisco and Oakland, Cal.—again giving official verification to the stand taken by the JOURNAL as long ago as February, 1898, in condemnation of the system which has now by universal consent been branded as spurious.

The session of the Gas Association lasted from July 10th to July 12th inclusive, and it was held, as usual, in the directors' room of the San Francisco Gas and Electric Company. Something over forty members responded to the roll call, after which the Board of Directors rendered its annual report, the main feature of which was the satisfactory recommendation that the names of 20 applicants be (and were) added to the permanent roll. Then followed the annual address of President John Clements, of Red Bluff, Cal., after which the routine business of the Association filled in the remainder of the morning session.

After luncheon, the technical portion of the programme was begun by the reading of the paper entitled "Some Notes on Larger Types of Gas Engines," by Mr. Crockett, its author. The paper proved to be a plain and convincing statement of what could be accomplished by the well-directed use of gas engines of large sizes, and his recital of belief was clinched by the statement that the San Francisco Gas and Electric Company had placed an order with the Union Gas Engine Company of San Francisco for a 300-horsepower gas engine as referred to above. The discussion on Mr. Crockett's paper was altogether too brief and it was indeed a disappointment that the members did not evince a knowledge, or at least an interest in, a subject of such vital importance to the lighting and power industry. A diversion from the programme was then made by the action of the Association in electing Secretary J. B. Grimwood as the Association's official representative to the International Congress of Gas Engineers, to be held in Paris in September next.

Dr. R. M. Powers, of San Diego, Cal., then read an able paper on "The Use of Crude Petroleum for Firing Benches," which, with the discussion that followed, tended to show that solid fuel could still be counted on to do good work in bench warming. The afternoon session was concluded with a paper by T. R. Parker, of Napa, Cal., on "Thoughts Suggested by Boiler Explosions."

Wednesday morning's session was opened with the paper by Mr. Humphreys which has already been referred to, which was followed by a lecture by A. S. Cooper, State Mineralogist of California, who, through his assistant, Charles G. Yale, gave an interesting tabulation of "Some Physical Characteristics of California Petroleums."

Officers for the ensuing year were elected as follows:

President—John A. Britton, Oakland, Cal.

Vice-President—C. E. Burrows, Walla Walla, Wash.

Secretary and Treasurer—J. B. Grimwood, San Francisco.

Directors—W. G. Barrett, Thos. Thompson, J. W. Thomas and A. L. Rice.

After suitable responses by the officers elect, Mr. Britton began the business of the second afternoon by reading his paper on "The Best Method of Introducing Gas Stoves," which brought about the liveliest and most favorable discussion had during the entire meeting. Then came L. P. Lowe's illustrative paper on "The Synthesis of Commercial Gases,"—an interesting and altogether invaluable treatise which evoked frequent applause—after which followed the "Wrinkle Department," edited by Geo. H. Hollidge of Merced, Cal., and the "Experience Department," edited by O. M. Gregory, of San Jose, Cal. The evening of the second day, Wednesday, was spent in a theatre party at the Orpheum to members and their families.

The third day of the meeting was devoted to an "outing" that was to be in the nature of a surprise, and those who attended and had never made the trip before, found no disappointment in the pilgrimage, for the entire party, numbering something like 200 in all, followed the example of the Transmission Association and spent the day on Mount Tamalpais, where, after luncheon, the contents of the "Question Box" were discussed. The return was made to San Francisco at 7 p. m. and at 9 o'clock of the same evening the members attended a banquet as the special guests of President-elect Britton. Were the literal truth to be spoken, it would be recorded that the banquet afforded the means by which most of the members were enabled to protract the meeting until the morning of the fourth day, despite the decision of the Board of Directors that the session should be limited to one day less.

INDUSTRIAL GAS.

The extraordinary demand for space in this edition of the JOURNAL has made it imperative that part XV of the serial by Frank H. Bates upon the above subject should be omitted until the August issue, when it will appear, and, it is hoped, be continued uninterruptedly until its conclusion.—THE EDITOR.

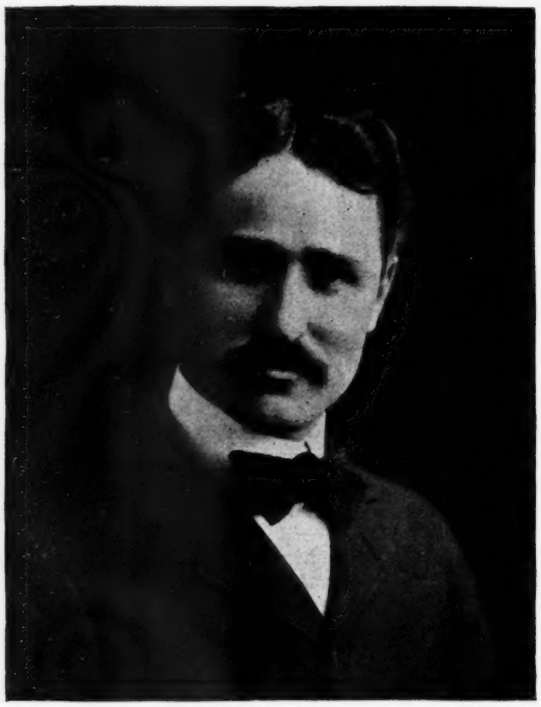
Arno suggests* that the power factor of a symmetrically loaded three-phase circuit can be determined from wattmeter readings alone by connecting the thin coil of the wattmeter across the terminals of the circuit containing the main coil, thus giving the value of $EC \cos \phi$, then by connecting the thin coil across the other two terminals of the star, giving a value for $\sqrt{3}\, EC \sin \phi$, whence $\cos \phi$ can be calculated.

*Science Abstracts, No. 1303, 1900; Vol. IV, page 484.

Personal

PROFESSOR CLARENCE L. CORY was educated in the common schools and entered Purdue University at Lafayette, Ind., his home, in 1884. He spent one year in the preparatory department of that institution, entering the regular four years' course in mechanical engineering in 1885, graduating in 1889.

Dr. Louis Bell became professor of physics and applied electricity in the fall of 1888, remaining at Purdue one year. This was during Professor Cory's senior year, and it was with Dr. Bell that he spent most of his time. It was during that year that Dr. Bell determined the efficiency of the Lafayette Electric Street Railway, which was installed in the summer of 1888. The plant consisted of two small Edison bipolar generators belted through a line shaft to a Corliss



PROF. CLARENCE L. CORY

engine. Sprague motor equipments were used, and about ten miles of track, with some heavy grades, were operated by electric traction. Prof. Cory worked with Dr. Bell on this test, the results of which created quite an interest in the electrical field. The current literature of the time contains a description of the plant and an outline of the experimental work and results. "Prof. Cory," says the electrical number of *The Purdue Exponent*, dated November 23, 1898, "may be considered number one in the list of graduates in electrical engineering at Purdue, he being the first student to elect the so-called course in applied electricity given by Dr. Louis Bell in 1888 and 1889."

During the following year Mr. Cory was assistant instructor in electrical engineering at Purdue at the time of the occupation of a new building by the engineering department. The plans of the laboratory had been made by Dr. Bell and much of the installation was carried out by Prof. Cory. The dynamo laboratory was an excellent one for the period, and included experimental machines for direct and alternating current as well as a 50-cell storage battery of the old "E. P. S." type.

The next year (1890) Mr. Cory became a graduate student in electrical engineering at Cornell University where he spent a large part of his time in the laboratories. A study of armature reaction and commutation, as affecting the regulation of direct-current generators, occupied his time during the latter part of 1891. That year's work, with that which followed, enabled him to take the advanced degree in electrical engineering at Cornell in June, 1891.

After leaving Cornell Mr. Cory went to Highland Park College, Des Moines, Iowa, as professor of electrical engineering. In connection with his position there he installed the electric light and power plant for the college which is still in operation, practically as installed, nine years ago. Des Moines was then, as it is now, a city where fuel is very cheap, and yet water power is used to a large extent in generating electrical energy. Tests were made by Prof. Cory on two of the plants in Des Moines and the reports to the companies showed the increased economy of using water power, particularly when the load was a continuous one during the day as in street railway work. He also urged the Des Moines Street Railway Company to discard their small 500-volt units, driven through belts and countershafting, and to install the largest generators then procurable.

In June, 1892, Prof. Cory was elected to the position of assistant professor of electrical engineering in the University of Illinois. At this time, as in many other universities, work in electrical engineering at the University of Illinois was under the direction of the department of physics, so that Prof. Cory was to have had charge of the electrical work under the general direction of the professor of physics, but before finally accepting the position in Illinois, the University of California called Prof. Cory to Berkeley to organize the department of electrical engineering. The University of Illinois, unwillingly however, allowed Prof. Cory to appoint a substitute to the position, thus making it possible for him to come to Berkeley. In May, 1899, after a visit through the electrical department in Berkeley, the President of the University of Illinois offered Prof. Cory the head professorship in electrical engineering in Illinois. Notwithstanding the pleasant circumstances and excellent opportunity, Prof. Cory declined the call in order to remain in California.

The electrical department of the University of California has been developed almost entirely by Prof. Cory. One particular difference between the work there and many other universities is that the electric light and power system is under the direct control of the engineering department. A 150-horsepower station is operated, giving light and power to the entire university, the plant being in operation averaging seventeen hours a day. In the seven years since the electrical department was organized more than 100 students have completed the work, and, it may be stated in passing, that a University of California man may be found in each of the three San Francisco offices of the largest electrical manufacturing companies.

Early during the present year Prof. Cory was excused from all general University duties for the next academic year—this step being initiatory to his entering actively into the engineering field. He has become identified with the Engineering Offices, 331 Pine Street, San Francisco, in association with E. H. Benjamin, A. M. Hunt and Wynn Meredith, and although this association is as yet of but a few months' duration, he has already become identified in a consulting engineering capacity with electrical enterprises in almost every portion of California. Nevertheless, Prof. Cory still retains his professorship of electrical engineering in the University of California, where he directs the work in electrical engineering and the operation of the electric lighting and power plant. Two of the most valuable papers ever brought before the Pacific Coast Electric Transmission Association, one of which appears in this issue of the JOURNAL, were from Prof. Cory's pen, in recognition of the inestimable worth of which to transmission interests in general, the Association bestowed upon him the coveted honor of honorary membership.